THEORY AND APPLICATION OF

CROP THRESHING TECHNOLOGIES

R.S. Devnani
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भाकृअनुप
ICAR

Indian Council of Agricultural Research
New Delhi

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Preface

THE present day agricultural technologies are to increase the yield levels from 2.0 to 10 tonnes per hectare, but they are not readily adopted as farmers' fear that modern changes and mechanization would create problems of social, economic and environmental type. To meet the increased food requirements of the growing and large population, the countries have to produce at local level or allow the import of produce from other countries to meet the demand of people in urban areas. The Government of India, through the Indian Council of Agricultural Research, New Delhi, launched the coordinated project on Research and Development of farm machinery and their suitability for different regions during 1965, for development, testing and popularization of farm machines on basis of local needs and agro-ecological conditions. This approach was followed because of the very weak economic conditions of the farmers in many regions. The local manufacturing was encouraged to reduce the final cost of machines essential for the farmers, as this eliminated the cost of transport and handling etc. It helped the farmers to directly interact with the manufacturer or fabricator to meet their requirements.

The International Rice Research Institute at Los Baños, Philippines was established during early sixties and they started developing rice production technologies for the small farmers of Asia. The agricultural engineering work conducted at IRRI resulted in development of much equipment for the crop establishment, interculture, plant protection, threshing and rice processing operations. The axial flow thresher for threshing of wet crop of rice was developed and popularized in many Asian countries.

The UNDP (ESCAP) started the net-work project as Regional Network for Agricultural Mechanization (RNAM) located at Philippines on popularization of agricultural machinery in Asian countries in 1978. The emphasis was to mechanize with machines useful for establishment, threshing and harvesting of crops. This program helped in identifying the most useful machines used by farmers and strength of the development activities in many countries. It helped the countries to get the man power suitably trained in advanced countries. It helped the small scale manufacturers to organize their activities for the benefit of famers. All these efforts resulted in development of appropriate equipment in these countries to mechanize agriculture.

The present book highlights the developments on thresher and threshing of many crops in many Asian, African and Latin American countries where effect of green revolution are visible. The machines from advanced countries were not compatible to their situations both from socio- economic conditions and technical levels. It was a challenging job for the designers to closely look to farmers' demands and make machines to suit their needs and not the machine which had high capacity resulting in low cost of operation.

The high capacity crop threshing machines from advanced countries can perform the job in less time and at low cost. However, even in present situations, they are acceptable only for custom hiring purpose, as they take away work or jobs from the farm workers. The sustainable life can be maintained only when people are in harmony with the nature and society. This is particularly applicable to farming communities in many Asian, African

and Latin American countries. Therefore, the development of agriculture would require appropriate machines which would help in sustaining the ecosystem and needs of the rural population.

The authors have compiled the large number of designs of threshers and shellers of different types suitable for many crops grown by the small farm holders with land holdings in the range of 0.4 ha up to 20 ha. For the farmers in Asian, African countries getting all the grain and the straw of the crop is important to them, as straw is used as animal feed. Presently the value of straw is close to 50 to 60 % the value of grain in India. Thus farmers' survive even with such a small size machines and farm holdings as they utilize all the components of crops.

Hence, the threshers and machines developed and accepted by the farmers as reported in the book would help the extension engineers and fabricators to popularize mechanize threshing operation. The aim should be to develop and introduce appropriate machines to promote their use which are in harmony with the ecological and social system followed by the farmers and small scale fabricators and need not be solely based on the least cost basis or on the size of farm. The need for appropriate agricultural machines is felt more acutely when there is reduction in farm labour due to migration to urban centres and intensive agriculture is followed. Thus, mechanization is usually more intense near urban areas. Often the need is to have a multi-purpose machine on the farm because single-purpose machine have low rates of utilization.

The information on such low cost threshing technologies developed and popularized is made available in this book. The aim is to help farmers use the machines to reduce the drudgery. It is hoped that it would serve the purpose of mechanization of threshing operation at all levels of farm holders in most of the developing countries.

R.S. Devnani and T.P. Ojha

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1 Introduction

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All biological plants have some utility for human and animal kingdom. However, on plants a few operations must be performed to separate the useful component as the grain or seed. In this process the two necessary operations performed are (1) harvesting and (2) threshing. In this book efforts have been made to describe the different threshing operations pertinent to the biological materials to separate the components (grain, kernels, nuts, fibres) from the straw or plant material in different manner relevant to the physiology and usefulness of the materials. However, efforts are always made to retrieve the maximum amount of usable products, which would otherwise go waste. Mechanization of these operations have gone a long way in preventing the losses and reducing the drudgery of workers and animals which form the major source of energy in completing the traditional system of harvesting and threshing operations. Most of the underdeveloped and developing countries where population density is high and consequently the farm holdings are small, the non mechanized or partially mechanized systems are in vogue even in 21st century. In brief the different technologies as applied to these operations were the skills available with the farmers practicing small level farming. The research and development activities and adoption of perfected technologies leading to higher level of land productivities of cereals, oilseeds, pulses etc; have forced to go in for mechanization of the two most important operations viz. harvesting and threshing all over the world. In spite of efforts made by research and development groups, the industries, financial institutions and National governments, the adoption of mechanization have been a slow process, one cannot claim it revolutionary. In a very broad sense, the mechanization of these two operations can be discussed under the following two periods in so far as the developing world is concerned. The two periods are the pre- and post-green revolution eras which took place in agriculture covering the developing countries. The most widely accepted traditional technologies used by the farmers are the sickles and manual beating or animal treading of crops (Fig.1.1). It remained the most prominent system till 1966 in India, by this time green

Fig. 1.1. Threshing of crop by animal treading.

revolution era began to deep root in food grain production all over the world. Soon after that period, the tradition bound farmers of Indian subcontinent and South East Asian countries began to feel the pinch of farm operations and usefulness of timely harvesting and threshing operations to obtain the maximum returns from the agriculture. These two operations for crops other than paddy and wheat remained untouched till late 1980's by the time the productivity of other crops started showing promising results. The research and development institutes made some promising contribution in developing high yielding varieties of all other crops and government agencies paid attention to promote the application and development

Fig. 1.2. Threshing of crop by tractor treading is still practiced in India.

of irrigation water, chemical fertilizers and plant protection measures thus increased the needs of mechanization. However, some of the farmers who owned tractors took advantage of that for threshing wheat and paddy crops as shown in Fig. 1.2.

Activities and efforts

The term harvesting and threshing have wider applications in agriculture and allied disciplines. These terms have different meanings in traditional low cost and improved modern technology being practiced in developing countries. Traditional methods involved use of simple hand tools, manual labour and animal power in different operations from harvesting to threshing and bagging to storage or till the utilization of produce. Harvesting by sickle, threshing by manual beating or animal treading and for separating the grain from chaff, the traditional winnowing techniques are used. Table 1.1. presents the most popular traditional and improved technologies associated with these operations. The improved technologies developed by research and development institutions and local industries have gone through numerous changes involving field evaluation techniques for product improvements by the research engineers, manufacturers and traditional fabricators. One can be proud of numerous devices developed in India and neighbouring countries. In this process the role of National research institutes and Regional Network of Agricultural Mechanization (United Nations Development Programme (UNDP), Economic and Social Commission for Asia and the Pacific (ESCAP)) centres in different south east Asian countries have to be appreciated. It is to admit that these developments were closely associated with the green revolution era of paddy and wheat regions of RNAM (Regional Network for Agricultural Machinery) participating countries. The development with regard to South Asian Association for Regional Cooperation (SAARC) countries in general

Table 1.1. Harvesting and threshing technology applied to agriculture commodities in most of the Asian countries including India.

Crops	Period	Machines and techniques adopted for operations
Paddy	Before 1966	Manual beating on bench, animal treading
	After 1966	Pedal operated wire loop thresher, tractor treading, IRRI axial flow, rasp bar thresher, multicrop thresher
Wheat	Before 1966	Manual beating, animal treading
	After 1966	Tractor and power operated hammer mill type, spike tooth thresher 1968, Multicrop 1976
Oilseeds	Traditional	Manual beating or animal treading
	After 1980	Wire loop on drum or peg cylinder
Pulses	Traditional	Manual beating or animal treading
	Improved after 1980	Spike tooth type, multicrop threshers and winnowers
Fibre crops	Traditional	In field drains and ponds, Water retting and manual cleaning
	After 1980	Roller type scutching machines
Coconut	Traditional	Manual dehusking and sun drying
	After 1980	Mechanical devices introduced

and India in particular have the following important stages. The mechanization of any farm operation is closely related to the size of land holdings, the household income of the farmers and the mechanization policy of the state and central governments of countries. Nevertheless the economic status of the farmers and promotional role of the agro machinery industries have paid real dividends in achieving the goal of mechanization. Table 1.2 presents the size and number of land holdings in India. In all probabilities the picture remains the same in most of the SAARC countries. In all probabilities the picture of mechanization of these two operations can be classified as follows:

i) Use of traditional tools and techniques by majority of small landholders. The custom hiring services of power threshers wherever these are available are utilized.
ii) In case of large size holdings, for crops like wheat, the threshing operations have been mechanized in most of the regions of India. Whereas, the threshing operation of paddy crop harvested manually is mechanized in the traditional paddy growing regions.
iii) The holdings size above 2 to 4 ha and above are considered to be partially mechanized with major emphasis on the use of thresher on ownership basis or on custom- hiring basis.

The average size of holding in case of marginal farmers is 0.40 ha and the average size of holding is about 1.57 ha (1990-1991). The total number of farm holdings in 1971 was 71 millions and in 1991 it was more than 105 millions. However, this number reduced to 90 million by 2003. This number is increasing due to further divisions of farm families. The number of marginal farms increased to 62 millions in 1991. Only 2 % of farm holdings can be considered in the size of above 10 ha. In rural areas, 45.3% of households have size of cultivated land of 0.20 ha (Table 1.3-1.7).

The total area under crops in India during 1990-91 was 185.48 million ha with rice covering 42.6 million ha and wheat 24 million ha, coarse cereals 36.3 million ha, pulses 24.6 million ha, oilseeds 24.1 million ha, besides fibre crops 8.5 million ha, fruits and spices 17.67 million ha, vegetables 4 million ha etc.

Table 1.2. Trends in distribution of land holdings in India from 1970-91

Year	Marginal < 1 ha	Small 1-2 ha	Semi medium 2-4 ha	Medium 4-10 ha	Large > 10 ha	All India
Farm holdings, million number						
1970-71	36.20	13.43	10.78	7.93	2.67	71.01
1976-77	44.52	14.73	11.67	8.21	2.44	81.57
1980-81	50.12	16.07	12.45	8.07	2.17	88.88
1985-86	56.15	17.92	13.25	7.92	1.92	97.16
1990-91	62.11	19.97	13.91	7.63	1.67	105.29
Operated area, million/ha						
1970-71	14.56	19.28	29.98	48.23	50.09	162.14
1976-77	17.51	20.90	32.43	49.63	42.67	163.34
1980-81	19.73	23.17	34.65	48.54	37.71	163.80
1985-86	22.04	25.71	36.62	47.14	33.00	164.56
1990-91	24.62	28.71	38.35	45.05	28.89	165.6
Average size of holdings						
1970-71	0.40	1.44	2.78	6.08	18.76	2.28
1976-77	0.39	1.42	2.98	6.05	17.56	2.00
1980-81	0.39	1.44	2.78	6.01	17.38	1.84
1985-86	0.39	1.43	2.77	5.95	17.19	1.60
1990-91	0.40	1.44	2.76	5.90	17.33	1.57

Source: Agriculture Statistics at Glance, Govt. of India, New Delhi,1994

Table 1.3. Average size of operational holdings by size group

Category of holdings	Average size of holdings 2000-01	2005-06	2010-11
Marginal (less than 1 ha)	0.40	0.38	0.38
Small (1.0 to 2.0 ha)	1.42	1.38	1.42
Semi-medium (2.0 to 4.0 ha)	2.72	2.68	2.71
Medium (4.0 to 10.0 ha)	5.81	5.74	5.76
Large (10.0 ha and above)	17.12	17.08	17.37
All holdings	1.33	1.23	1.16

Source: Department of Agriculture and Cooperation (Agriculture censes 2010-11, Provisional), Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India.

Table 1.4. Land possessed and estimated number of farmers households

Land possessed (ha)	Estimated number of farmers households (lakh)	(%)
Up to -0.01	12.59	1.4
0.01-0.40	292.87	32.8
0.41-1.00	283.61	31.7
1.01-2.00	160.60	18.0
2.01-4.00	93.50	10.4
4.01-10.00	42.58	4.8
10 and above	7.75	0.9
All India	893.50	100.0

Source: National Sample Survey 59th Round (January-December 2003) Source Report No. (49859/33/1) Situation assesment survey of farmers, Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India.

But due to improvement in agriculture the production levels have multiplied many folds.

At present Asian countries are in position to meet out their food requirements. The crop area under agriculture is almost stagnant whereas the country like India needs 5-6 million tonnes of extra food grains every year to meet the demand of growing population.

Table 1.5. Land size distribution as per household and population in India.

Size of cultivated land, ha	Distribution, %	
	Household	Population
Up to 0.20	45.3	38.4
0.20-0.40	9.1	8.8
0.41-1.0	17.3	17.9
1.01-2.0	13.9	14.6
2.01-4.0	8.6	10.8
4.01-8.0	4.2	5.7
8.01 and above	3.6	2.5

35% of the households have cultivated land less than 0.005 ha.

Since the late 20th century the mechanization of harvesting and threshing operations are being done by way of custom hiring the machines owned by a group of traders or entrepreneurs who hire the machines and move the fleet from one state/district to other depending the maturity pattern of crops. The advantage of this trend has attracted the attention of the farmers of different states who find it beneficial to take advantage of custom hiring services. This trend of mechanization is particularly on increase in harvesting and threshing of cereals and oilseeds. A survey report indicated that custom operators move across different states of India covering a distance up to 2,000 km during the harvesting and threshing seasons with combine harvesters.

The status of mechanization of other crops namely coarse cereals, oilseeds and pulses are concerned the major emphasis has been the use of thresher for separating the grain from straw. Table 1.7 (A and B) indicates that the demand for the multicrop threshers would increase to thresh the crops other than cereals. The pulses have benefited the farmers as well as operators of multicrop machines. It is expected that the demand for threshers would continue to increase as labour availability is becoming problem in the rural India.

Development of threshers and shellers

The year wise developments in threshing and

Table 1.6. Trend in gross cropped area from 1971-91 in million/ha.

Crops	1971-72	1975-76	1981-82	1986-87	1990-91
Paddy	37.76	39.4	40.71	41.17	42.69
Wheat	19.14	20.45	22.14	23.13	24.17
Sorghum	16.78	16.09	16.60	15.95	-14.36
Millets	11.77	11.57	11.78	11.27	10.48
Maize	5.67	6.03	5.94	5.92	5.90
Other coarse cereals	9.35	10.11	8.13	6.60	5.58
Total coarse cereals	43.57	43.8	42.45	39.79	36.32
Gram	7.91	8.32	7.87	6.98	7.52
Pigeon pea (*arhar*)	2.35	2.67	3.00	3.15	3.59
Other pulses	10.89	13.48	12.97	13.03	13.55
Total pulses	21.15	24.45	21.15	23.16	24.66
Groundnut	7.51	7.22	7.43	6.98	8.31
Rapeseed/ mustard	3.61	3.34	4.40	3.72	5.78
Soybean	0.03	0.09	0.48	1.53	2.56
Other oilseeds	6.12	6.27	6.60	6.40	7.50
Total oilseeds	17.27	16.92	18.91	18.63	24.15
Cotton	7.80	7.35	8.06	6.95	7.44
Jute and mesta	1.11	0.91	1.15	1.07	1.02
Total cropped area	165.79	171.29	176.75	178.46	185.48

Table 1.7A Thresher population, annual production and projected demand in India (in thousands)

Thresher type	Actual population			Projected growth %	Estimated population	
	1972	1977	1982		1991	2000
Wheat	182.5	427.8	831.9	10	1845	3321
Paddy	13.6	37.5	131.8	15	270	594
Multicrop	9.7	18.8	61.3	15	135	297
Total	205.8	484.1	1025.0	-	2250	4212

Table 1.7B Thresher population, annual production and projected demand in India (in thousands)

Thresher type	Projected demand of threshers in India (in thousands)							
	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-2000
Wheat	328.5	337.5	346.5	355.5	364.5	373.5	328.5	391.5
Paddy	58.5	60.5	62.5	64.5	66.5	68.5	70.5	72.5
Multicrop	29.25	30.25	31.25	32.25	33.25	34.25	35.25	36.25
Total	416.25	428.25	440.25	452.25	464.25	476.25	488.25	500.25

shelling machines which have taken place in India are as follows:

- Development of ground nut decorticators during 1950-65 in the state of Gujarat and Maharashtra
- Development of cleaners and winnower for the threshed materials during 1965-75 at Institutes at Allahabad, Kharagpur and ICAR Institutes.
- Development of wheat thresher 58-59 in small scale industry, in Punjab and also at Allahabad Agricultural Institute, Allahabad in 1962-64 with assistance of Ford foundation.
- Development of grain and seed separation from pods, ears, panicles. (Traditional and improved methods). During 65-95 at the State agricultural Universities and Institutes.
- Role of tractors and rural electrification in promoting the use of power threshers 1970 onwards.
- Threshing studies on pulses and soybean during 1973-75 at Udaipur, Pantnagar and Jabalpur assistance of ICAR, New Delhi.
- Shelling and dehusking of maize crop during 1974-77 at Udaipur and Tamil Nadu Agri. Universities.
- From 1976 onwards with establishment of Central Institutes of Agricultural Engineering, Bhopal and two coordinating projects on Farm Implements and Machinery, and Harvest and Post harvest technology etc. Similarly the national level agricultural engineering Institutes were started or identified in most of the Asian countriessince1978,under(RNAMProject).
- Introduction of IRRI Axial flow threshers for rice crop since 1980.
- Introduction of Industrial extension services for production of agricultural machines at CIAE, Bhopal since 1980.
- Historical development of fibre extraction from fibre plants and coconut husk and shells using traditional and improved technologies along with the establishment of National level Institutes 80-85.
- Synthetic fibres and fibres of agricultural origins and rope making technologies.
- Straw and *Bhusa* (bruised straw) making, packaging and storage system development 1990-95.
- Industrial growth for agricultural mechanization during 20th century with traditional, semi mechanized and simple automation with respect to threshing, shelling, extraction of fibres of various field crops.

- Ergonomic studies on threshers and shellers including control of noise and pollution 2003 onwards
- Threshing of other crops having economic potential including spices and medicinal plants from 2005 onwards.

The production and productivity of agricultural crops increased manifolds in India and many Asian countries due to adoption of modern technologies in the agriculture during last five decades. The higher yield levels, multiple cropping, irrigation methods and availability of improved equipment influenced the farmers to adopt mechanization of threshing operations. This change not only helped them to reduce the field losses but also improved the quality of produce. The period of threshing of many crops is presently from 7 to 15 days. It is because of dry weather conditions either the crop loses its moisture in field fast enough to cause high shattering and collection losses or due to rains crop gains moisture and starts deteoraiting. The bottom line is to get the maximum amount of grain in a suitable condition to either store it on farm or dispose it in the market at prices for high profits. The methods adopted depend upon the availability of labour, the rates of wages, economic conditions of farmers and the cost and availability of machines. There is the growing trend of using threshers by farmers of rice-wheat region.

Stages of development

The low wage rates and low value of the crop forced the farmers in Indian subcontinent to continue to manual methods of operations till 1985. This was also true for many Asian countries because of economic conditions of the farmers. By 1985, many appropriate designs of rice threshers were made available in the market, but the rice farmers had not accepted those due to socio-economic considerations. They were not sure whether those machines would be useful to them in comparison to traditional method of threshing by manual beating the crop on hard surface or wooden plank etc. Even some farmers followed the practice of spreading crop on tar road and due to movement of vehicles got the crop threshed at no cost to them. It so happened that an economic analysis carried out by IRRI also approved the traditional techniques employed by the resource poor farmers owning small land holdings. The study of International Rice Research Institute (IRRI) Philippines reported the breakeven point for their least priced rice thresher as compared to manual threshing the farmers should thresh at least 36 tonnes of paddy per year. This amounted to at least 6-8 ha of rice crop area with the farmer. This was for the low cost a machine without cleaning system and costing only $500 at that time.

The case of wheat crop threshing operation was different at least in India. Here the green revolution in wheat increased the production and productivity levels to high levels and thus the development and introduction of wheat threshers was essential. It caught the imagination of farmers in the wheat belt as there were government agencies to procure the wheat grain immediately from the farmers to meet the demand of public distribution system. Thus threshing of wheat crop started around 1962 but the growth of threshers continued at own pace during the next 20 years. The threshing of wheat crop was a great drudgery by animal treading during hot summer months. The wheat threshers further helped in introduction of other machines like tractor, tine cultivator, and tube well with pump-set, trailer and seed drill in the wheat growing regions.

The development of wheat threshers was indigenous efforts of industry, research organizations and the farmers of India. The machine so developed did separation of wheat grains from straw and produced the straw in the completely bruised form to be used by the farmers as animal feed. The cost of wheat thresher of 5 hp range weighing 350-400kg was ₹ 6 000-7 000 (US $ 500) during late seventies.

The farmers in many Asian countries produce not only cereals but also a number of other crops like coarse cereals, oilseeds such as sunflower, safflower, groundnut, rapeseed, soybean and pulses such as green gram, bengal gram, pigeon pea, green peas, etc. Consequently a wide range of threshers have been developed to meet the requirement of different crops. The ultimate aim of the farmers was to have a multi-crop thresher that can thresh most of the crops in a desired and profitable manner. The thresher besides doing the basic job of threshing should also perform with minimum use of energy and little hazard to the operator and without creating environmental pollution and at the cost, which should not be more than the traditional methods. Hence multi-crop thresher of 5 hp range was developed during 1984-85 at CIAE Bhopal. In rice, thresher should be able to separate the grain from panicles at high rates without causing damage to grain and straw. As the rice crop is harvested at high moisture level therefore satisfactory threshing at high moisture level is considered as the main criterion. The other criteria are that of high output of machine and labour requirements low to justify the use of thresher by the farmers.

Sorghum and maize crops are harvested as ears and, therefore, the grain to non-grain material ratio is high and thus the output of thresher for these crops is high. However, in case of sorghum the quality of grain is affected by the quantity of spiklets on threshed grain, which is around 10-12%. In maize the grain gets the pieces of broken cob hearts if the cobs are dry. In pigeon pea and mustard crops the plant stem is hard and thick. It is difficult to use the throw in type thresher to thresh the whole plant. Thus the output is low when thresher is used to strip the pods. The plant stems are used as domestic fuel and also for thatching of houses thus farmers want complete plant stems.

In soybean the seed is very tender and is easily damaged if threshed at high threshing speeds generally employed in case of rice and wheat threshers. Therefore it should be threshed without damaging the seed to fetch farmers more profits and have minimum of grain damage. Finally the multi-crop threshers of axial flow, semi-axial flow and radial flow type were developed during 1995-2000 to meet the farmers' requirements. Due attention is being paid to make machines safe for the operators and avoid environmental pollution which is highly undesirable for public at large.

The crops are either easy to thresh or difficult with very high and low grain per cent, at high moisture level or when they are dry. The straw may be required in bruised form or in undamaged condition. The crop straw length may be short or long. The plant stems may be brittle or very fibrous. These wide variations in crop characteristics require wide range of adjustments to make a thresher multi-crop type. Beside the threshing operation machine should be safe to the operator, be pollution free and energy efficient. Therefore continuous efforts are going on to make better and viable machines for the farmers. The main objectives in threshing is to harvest the crop at optimum level and recover maximum of grain and material other than grain as both the items are useful for the farmers. The technology adopted by the farmers depends upon the economic conditions and wages rates of the workers. The role of various agencies in popularization of threshers is very important and because of efforts of numerous agencies that mechanization of threshing has been achieved to a level as it is today. Still new innovations are being introduced to remove human drudgery and create a safe machine. The efforts will continue to achieve the desirable results in the best interest of farmers.

❑

2 Thresher Classification and its Components

Classification based on methods of crop feeding	10
Classification based on type of threshing drum	10
Classification based on flow of crop	12
Classification based on the crops to be handled	12
Cleaning system of thresher	12
Stacking and bagging units	14

The modern thresher is a machine or equipment which performs five unit operations given below:

1. Feed the harvested crop in an even stream free from bunches to the threshing unit at the desired feed rate.
2. Thresh or shell the grain out of the ears or heads or pods with the threshing unit.
3. Separate the straw from the grain and chaff and separate the chaff, dirt and weed seeds from the grain using cleaning system or shoe.
4. After threshing and separation of grain, deliever the straw to a stack away from machine.
5. Deliever clean grain-using auger and elevator to bagging unit or grain tank.

The machine should be portable type and fitted with suitable safety devices. The above operations are performed by the following components of the machine:

- Feeding tray or chute or crop conveyor,
- Threshing cylinder, concave and its accessories,
- Straw walker or straw thrower or an aspirator blower to blow out chaff and straw,
- Cleaning shoe for removing debris from grain, and
- Auger with grain blower, or conveyor at grain outlet for the bagging.

However considering the situation of small farmers, the thresher means only a threshing unit. The operator in sequential order performs the other operations manually. This is practiced only to reduce the load on the operator of doing the heavy and tiring type of activity and reduce the cost of machine to a minimum.

The small machine have hold on type feeding system. The bunch or bundle of crop is held in the hand until the cylinder detaches all the grains. Since straw is not damaged in this process, the simple machine is popular in all the rice growing regions where straw is widely used by farmers as animal feed, for making of mats, thatching of roofs etc. Thus rice threshers have been developed to meet the requirements of different categories of farmers.

In power operated threshers, there are conveyors and feeding devices that convey the crop bundles to the threshing units. In case

of throw-in type units, the whole plant mass is fed into the threshing unit. Here the grain is separated due to impact action of spikes or bars of threshing cylinder.

Classification based on methods of crop feeding

The method of feeding the crop in the threshers is classified as follows.

Manually fed types: The operator throws the whole mass of plants into the threshing unit. As the operator is working continuously doing the job the output of this system is limited to his work capacity. Thus these threshers have maximum limitation of giving output capacity in the range of giving of 400-500 kg/hr.

Mechanically feeding type: In these machines the crop fed to the feed conveyor is approximately in an even stream to the threshing cylinder. To prevent feeding crop rapidly, crop-retarding fingers are provided to hold the crop from being drawn in too rapidly into the cylinder. With these devices the threshers of high capacity are developed. The output of these can be more than 1000-1500 kg/hr.

For still high capacity output, it is recommended to use combine harvester, which will not only harvest but also thresh the crop at very high work rates.

Classification based on type of threshing drum

The second component of thresher is the threshing unit and for threshing rice crop three types of cylinders are used (Fig 2.1).

Wire loop cylinder: In this cylinder the wire loop of same arch are attached on the periphery of cylinder in form of helix. This is useful for stripping the grain.

Wire loop without concave (overfed type): In this arrangement there is no concave and exhibits excellent performance with hold on type method of feeding. The crop moves over the top of cylinder.

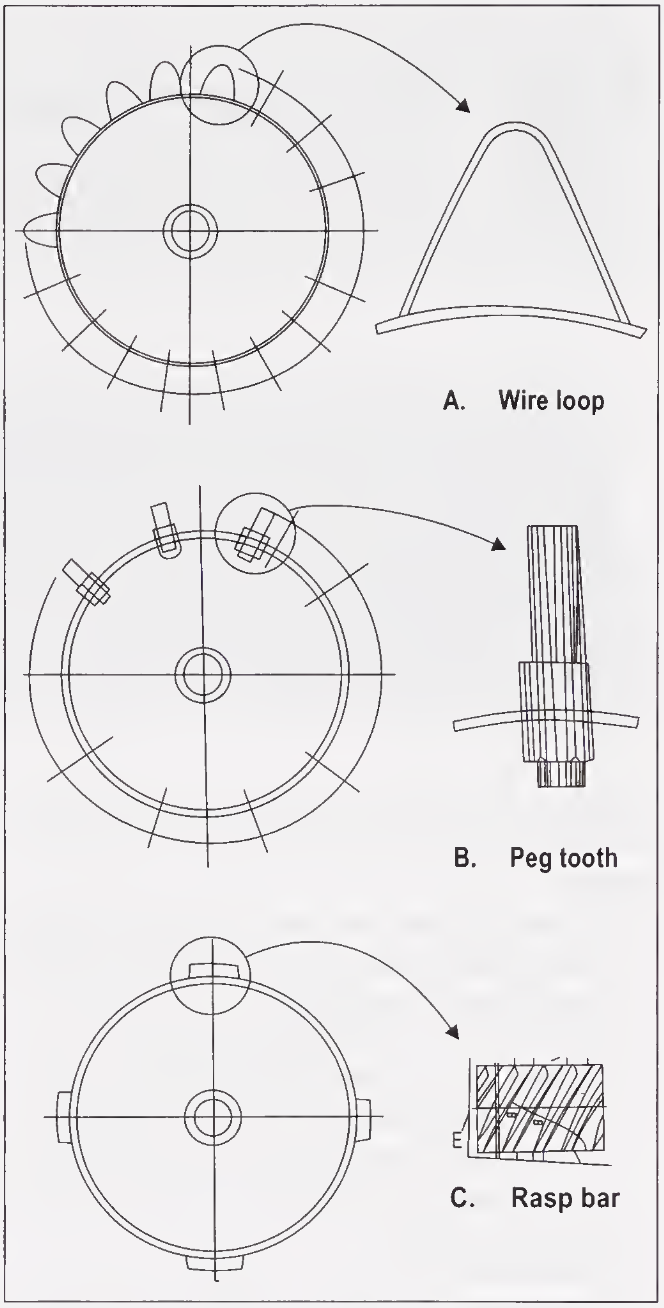


Fig. 2.1. Type of threshing cylinders used for threshing of rice crop.

Wire loop with concave (underfed type): This arrangement is also excellent for threshing of rice crop with hold on type method of feeding. Here the crop is fed into the cylinder at tangential angle and the crop is held under the threshing cylinder. The cylinder speeds for threshing are in the range of 11 to 14 m/s. In case of small rice thresher again there are designs, which are single drum type (Fig. 2.2).

This can be underfed or overfed type system (Fig. 2.3). In underfed type design there are chances of cylinder chocking due to variation in crop moisture conditions or drum speed. This problem is less in overfed threshing cylinders.

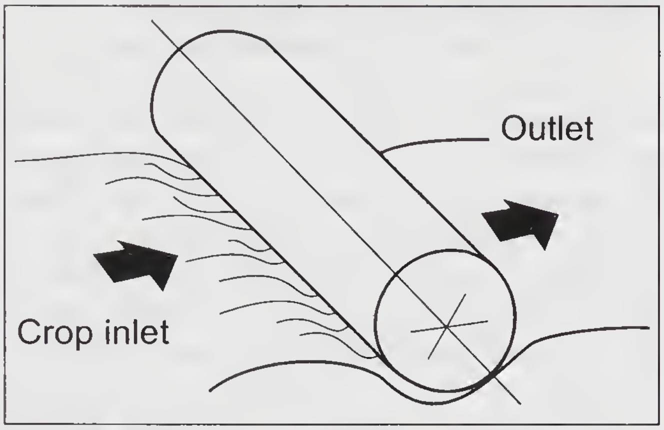


Fig. 2.2. Cross flow, tangential flow or through and through threshing drum.

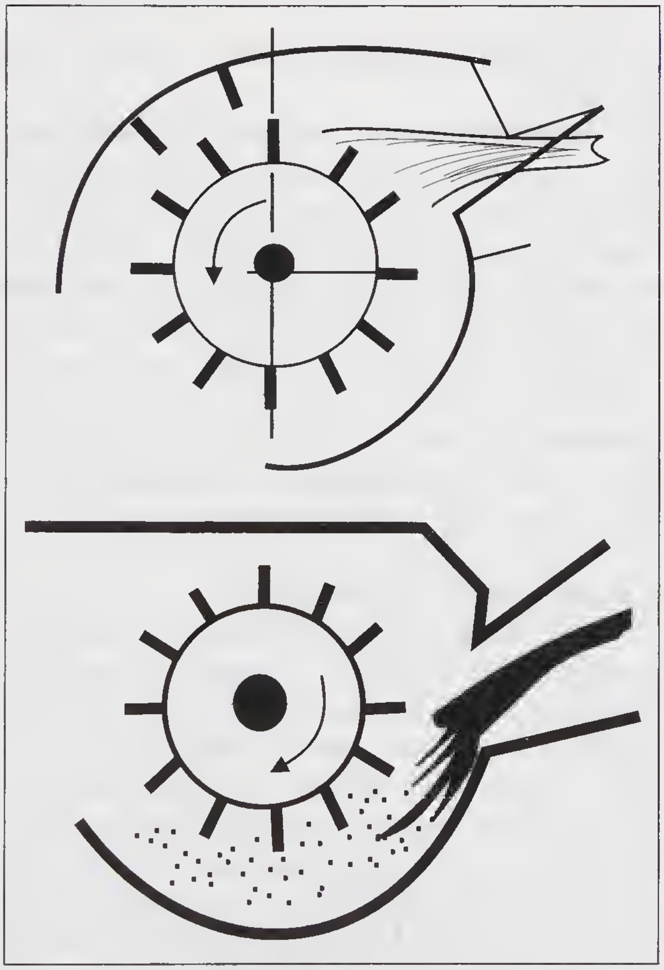


Fig. 2.3. Overfed and underfed type threshing drum arrangements.

Peg tooth and spike tooth type cylinder: The spikes or pegs of equal length are attached on the flat bars mounted on the cylinder. In European designs the spike tooth are also fixed on the concave and the teeth on cylinder move between the stationary teeth on the concave. This type of arrangement works well with throw in type feeding system and threshing is less affected by changes in the cylinder speed. In most of the spike tooth threshers developed in India or Asian countries the spikes are not used on the concave. There may be bruising spikes mounted at the outer end of concave when straw is to be bruised otherwise they are folded out of the unit.

Rasp bar cylinder: In this machine the rasp bars are mounted on the threshing cylinder and when crop is fed into the machine the threshing action occurs due to impact and rubbing action of rasp bars over the concave made of flats and round bars.

Multi drum type threshers (Fig. 2.4-2.5): There are usually two drums in these machines. These drums are in series rotating in same direction or placed one on top of the other and rotating in different directions. These are as shown in Fig. 2.4.The most of the threshing occurs at the first drum and hard to thresh grain is threshed at the second drum, which is rotated at higher peripheral speed. The material movement inside the threshing chamber is either flow through or radial type. The double drum type of threshing is most efficient in terms of recovery of the grain and can be adopted for multicrop threshing, but it has higher power requirement due to use of two drums. It utilizes the underfeeding system of feeding and threshing the crop.

Auxiliary drum type: It consists of two threshing drums, one drum acting as the major threshing cylinder and the other one acting as an auxiliary or helper to the main drum. It utilizes the mid feeding system and threshing of crop.

Dual drum type: The arrangement can be an

assembly of one cylinder over the top of other and cylinders rotating in different directions. It utilizes the crop feeding at middle of threshing drums for threshing the crop. (Fig.2.4)

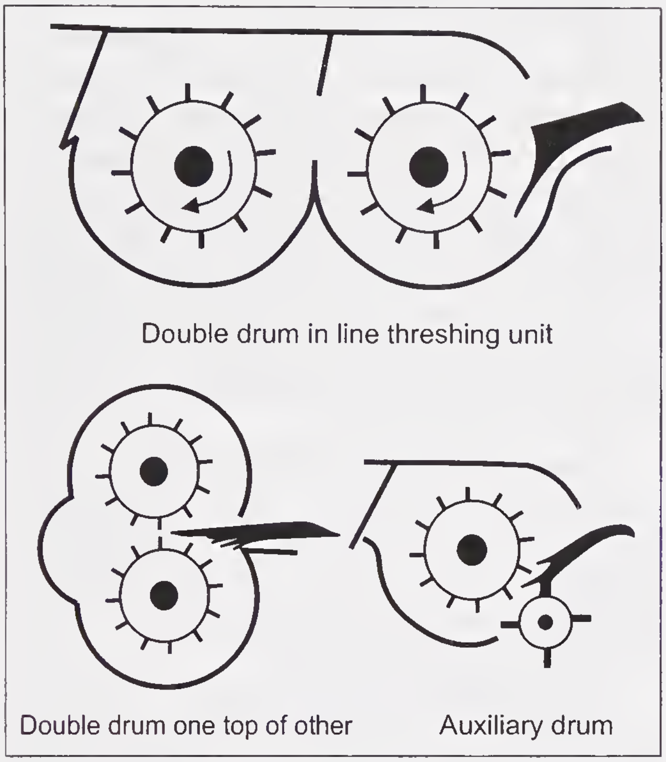


Fig. 2.4. Different design layouts of multi-drum cylinders.

Classification based on flow of crop

Based on the movement of material in the cylinder and concave unit, the threshers are classified as follows:

Flow thru or tangential flow or thru and thru thresher: The material is fed between the revolving cylinder and the stationary concave and it goes straight out of the thresher unit tangentially. About 65 to 70% of grain flows through the concave and remainder is separated in the subsequent operations.

Axial flow thresher (Fig. 2.6A–C): The material is fed between the revolving cylinder and concave on one end and it goes around the cylinder axially or helically and is discharged out at the other end of thresher laterally or axially. In this type of machine more than 90% of grain is separated from the straw at the cylinder. It means most of grain threshed is recovered through the concave as the mass of threshed crop is rotated spirally along the length of cylinder.

Axial flow designs are useful for threshing crops at high moisture level with less of grain damage and for high output capacity.

Radial flow type thresher: The material is fed between the vertically revolving cylinder and stationary concave and goes out of the thresher in radial direction. The bottom portion of concave acts as grate and sides are given rough surface to act as straw bruising surfaces. The entire separation of grain takes place in the threshing unit and entire mass falls on the top sieve of cleaner where aspiratory blower removes the straw. In this thresher the power input is high because of handling greater amount of crop material and for breaking or tenderizing the straw for use as animal feed.

Classification based on the crops to be handled

The threshers are also classified based upon the crops likely to be threshed in the machine. Thus we have rice thresher, wheat thresher, thresher for pulses, maize sheller, groundnut thresher etc. When the thresher is designed to thrash more than one crop it is known as multicrop thresher. By making provision to change the speed of cylinder, one can make thresher suitable for other crops. This type of unit has comparatively less cost of operation to the farmers due to longer annual use.

Cleaning system of thresher

The large volume of straw is handled through the machine; therefore cleaning involves separation of loose grain from the mass of straw and use of cleaning shoe to remove dust weed seeds and light grain. The use of straw walker does the separation of the chaff from the grain and the fine and light impurities are removed by the air blast and sieves. The component like thresher beater placed behind the threshing drum, moves the straw on to the straw walker.

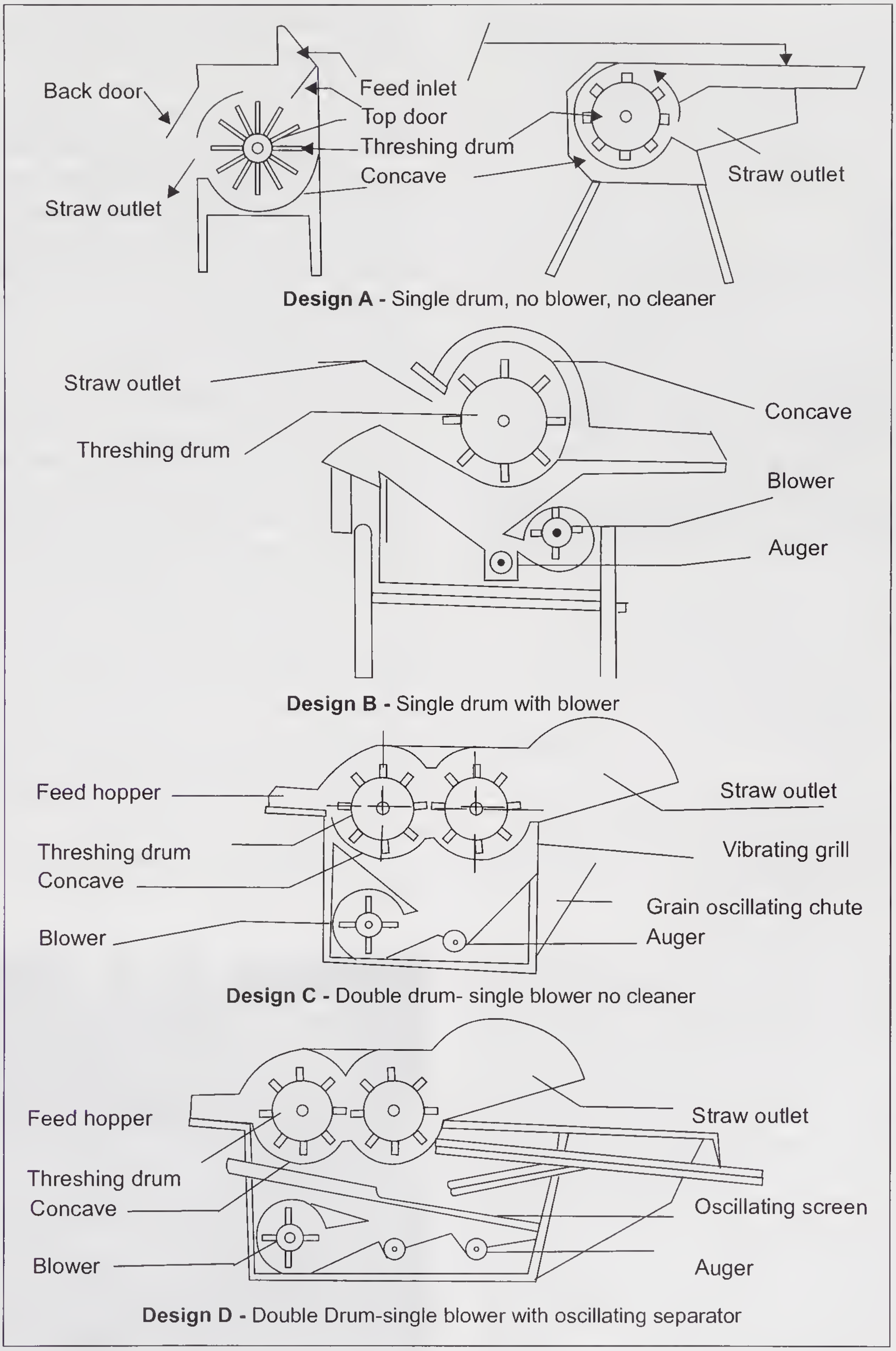
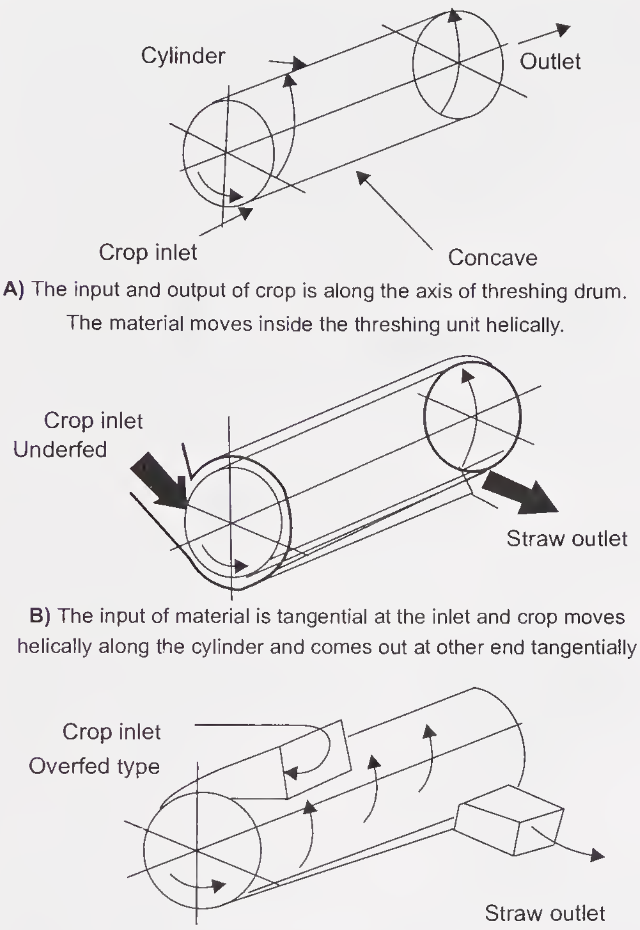


Fig. 2.5. (A-D) Different types of thresher configurations used for small threshers in Asia (*Source:* Torrizo E. M. *et al.*1980).



A) The input and output of crop is along the axis of threshing drum. The material moves inside the threshing unit helically.

B) The input of material is tangential at the inlet and crop moves helically along the cylinder and comes out at other end tangentially

C) The input of material is overfed and comes out tangentially at outer end. The material moves along the cylinder helically.

Fig. 2.6. (A-C) Different modes of material flow through axial threshing unit.

The straw walker is the mechanism, which causes agitation, and stirring of the mass of straw and grain to separate the grain from straw. The grain falls into the grain pan below and the straw walker moves the grain to the cleaning shoe and the straw is moved out of machine. The cleaning unit of thresher does the job of separation of straw, chaff, and empty kernels, very fine and light impurities, soil particles, and weed seeds from the grain. In simple form the straw and chaff are separated manually by dropping the threshed mass of grain through a crosswind. This can be done in naturally occurring wind or mechanically produced wind as in case of winnowing fan.

For rice thresher (Fig. 2.7) the cleaning system depends on the method of feeding the crop and the capacity of the machine. In hold on type machine, only grain with a small quantity of straw is collected in grain pan. In such cases a simple blower can do the job of cleaning the grain. The grain scalpers were used to remove chaff and dust from the threshed grain in case of rice crop or when tractor treading or animal treading were practiced on the farms.

Stacking and bagging units

In general there are two straw stacking devices used on the threshers, and these are:

Conveyor stacker: It consists of an endless conveyor of slat type used to carry the straw from the thresher to the straw storage racks. It can be direct type or swinging type.

Air blower: It consists of a fan or blower with a vertical discharge pipe or telescoping pipe to discharge the bruised straw in the storage bin or on covered trolley or on floor making a pile of straw away from the machine for use on the farm as animal feed or for commercial use. The air blower is provided with a swinging type outlet pipe so that discharge of material can be changed without shifting the machine. The power or

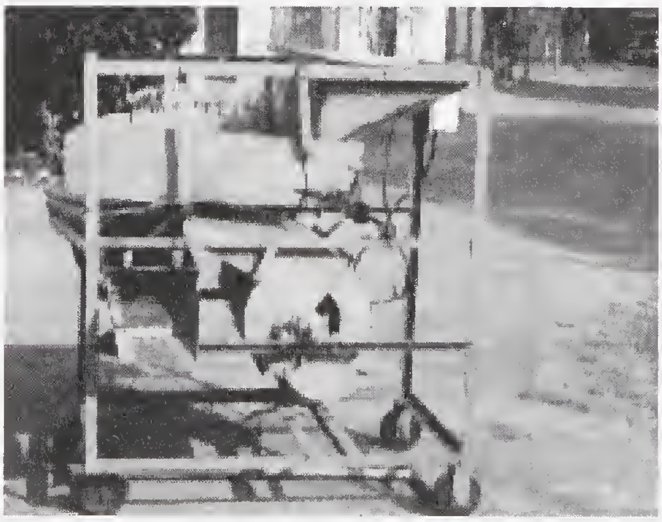


Fig. 2.7. CRRI Paddy cleaner used for cleaning of threshed crop after tractor treading.

energy requirements are high in air blowing of material.

Grain collection

From the cleaning shoe of the thresher a conveyor collects the grain. The grain is mostly conveyed by auger conveyors to the bagging unit or to the storage bin or into trolley for moving it to the final destination. Belt conveyors are also used in moving the clean grain from cleaner to storage bins. In small thresher the grain is collected on a tray or into container to be lifted manually to fill the bags.

There are number of ways of classifying the threshers based upon the crop to be threshed, size of machine, size of power source, the flow of material through the machine and also based on special features of machine and the number of workers used to operate it and the size of power unit etc. The main purpose of the thresher is to separate the grain from the straw, from ears, from panicles etc. The farmers have also interest not only in grain but also in the material other than grain. This is because the biomass so available is used as animal feed or for other commercial applications. Hence thresher may be defined as a machine to separate grain from plant materials without incurring any loss of material and provide all the grain and straw in the form best suited to the farmers. Timeliness of operation is another feature of the machine which is very much required after the harvest of crop by the farmer. Thus farmer likes to benefit from use of thresher in whatever manner it is possible.

❑

3 Rice Threshing and Threshers

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Rice crop is grown in most of the Asian countries. It is the staple food for most of the world's population. In India, it is grown in an area of approximately 42 million ha and production is above 110 million tonnes. China and Japan are also the largest producers and consumers of rice. The threshing of rice crop is very easy and the farmers in most of the Asian countries thresh the crop by beating it over a hard surface such as a plank or bench or a bamboo frame. This action is enough to detach the grains from the plants. As the small rice farmer uses the grain for his own family and straw for the farm animals or other household purposes. This method of threshing rice crop remained an accepted practice for a long time and even today. However, the introduction of rice thresher has made some difference in the system in so far as the small farmers are concerned. The mechanization of rice threshing, therefore, involved the evaluation of a few of Japanese machines of different types and sizes, which were developed during 1945-46 to meet the requirement of small farm holders of Japan.

Pedal operated thresher

The mechanical thresher for threshing of rice is the pedal operated machine, which originated in Japan during the early stage of mechanization. This thresher was also very popular in many Asian countries during (1960-1965). In Taiwan a team of 4-5 farm workers were engaged on each machine and the crew moved in circle. While two workers were threshing, the others were collecting and bringing new paddy bundles. The cylinder is rotated at speed of 300 rpm and the wire loops

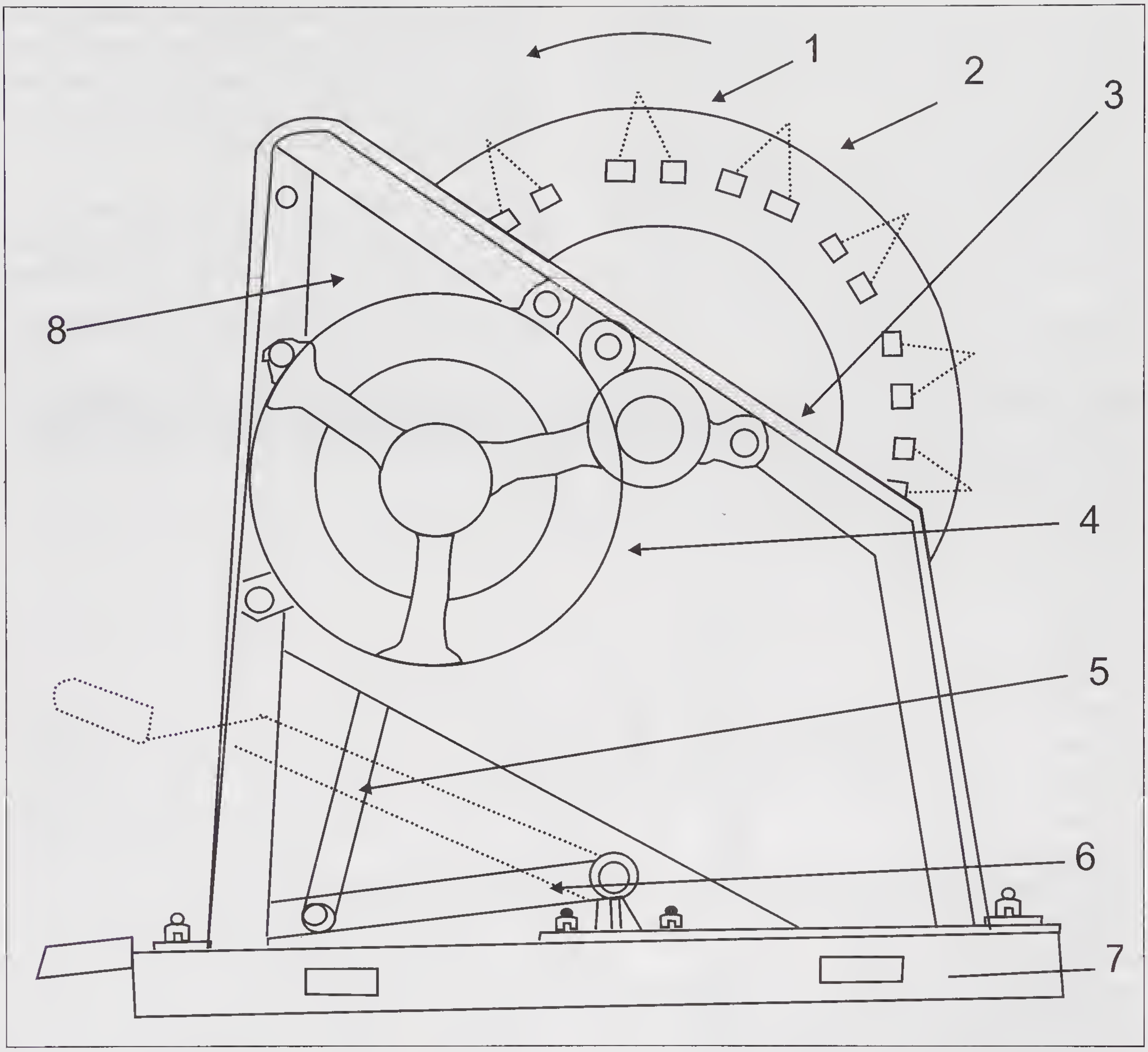

Fig. 3.1. Typical pedal operated thresher for paddy. 1, Threshing drum; 2, Wire loop teeth; 3, Frame; 4, Gear drive casing; 5, Connecting arm; 6, Pedal lever; 7, Base frame; and 8, Side cover sheet.

on it are able to detach the grain completely. The inertia of cylinder keeps the drum rotating and the worker tries to speed up the machine by operating the crank lever by a foot pedal. A few machines were imported in India during 1956-58 and distributed for evaluation. In rice growing regions of India local fabrication of paddy threshers of pedal operated machine were taken up (Fig. 3.1). There is no cleaner with the thresher. The test at International Rice Research Institute (IRRI) Manila indicated an output of 30-70 kg of paddy grain per worker per hour. However, comparative field tests were performed in Indonesia, India and other countries to understand the suitability of the machine vis-a-vis local method of threshing. Further tests at Sukamandi in West Java in 1979 on different varieties of rice crop indicated the average threshing capacity of the farm

worker as 25kg/man-hr for hand beating and 31kg/man-hr by trampling under feet. These values are also comparable to results of tests conducted in India.

The details of power requirement for rice harvesting on hectare basis (Table 3.1) indicates that there is not much saving in labour when pedal operated thresher was used as compared flail threshing or beating the crop on bamboo frame etc. Though this thresher was introduced but due to poor economic condition of farmers it was unable to impress them and could not be accepted by them particularly in India.

Power operated mechanical threshers

Japanese power threshers are classified according to method of feeding the harvested

Table 3.1. Power requirements for rice harvesting in man-hour, animal-hour and rated horse power-hour per hectare (*Source:* Johnson 1963)

Operation Activity	Man-h/ha			Animal-h/ha			Rated hp-h/ha		
	Min	Max	Avg.	Min	Max	Avg	Min	Max	Avg.
Hand harvest panicles with knife	--	--	240						
Hand harvest with sickle on tonne basis	--	--	69/ tonne						
Tractor and binder (40 hp)									
Binding	4.0	--	--				80		
Stacking	8.0	--	--				240		
Threshing	12	30	--				--		
Hauling	02	--	--				240		
Combine, 2 man crew (60-80 hp) In USA	2.2	7.5	4.4						175
In tropics	3.2	21.5	6-12				100	600	180-360
Foot threshing	200								
Flail threshing per tonne of crop material	16	35	20-30						
Beating on bamboo frame	16								
Pedal thresher	8-10	25	100						
Buffalo trampling	60			150					
Oxen trampling	89			178					
Japanese power thresher 0.5-3hp	48	197	100				15	25	
Values on tonne basis	20	25					3	5	
Treading with tractor standard			80				55	150	80
Tractor and disc harrow/tonne basis							50	80	
Stationery large thresher	13	30					90	180	
Cleaning of grain tossing in air/tonne	10								
Field winnowing with hand fan/tonne			6.7						
Fan mill, hand operated/tonne basis	1.5	7							
Chaff sieve per tonne	4.0	8.0							

crop. These are i) Hold on type ii) Mechanical feeding type and iii) Throw in type.

Hold on type: In this thresher feeding is manual. The heads of cut crop are fed into the threshing cylinder and the crop is held in the hand. The crop bundled is turned to detach all the grains from the straw. The threshing cylinder length is designated according to number of workers used during the operation. For cylinder length of 450mm one operator is used. The recommended lengths of machines for two and three workers are 600 mm and 900 mm respectively.

Mechanical feeding: The feeder on thresher does the feeding of the harvested crop bundles into the threshing drum automatically, therefore, the threshers are known as automatic thresher. Here the crop is harvested with a reaper binder, which makes the crop bundles of small size (2 kg in weight). These threshers are also classified according to the length of cylinder as small, medium or large size machines. The cylinder lengths recommended for these threshers are 350 mm, 500 mm and 600-1200 mm respectively.

Throw in type: In this thresher the harvested crop is thrown into the machine in full and is finally threshed. Main parts of the Japanese power thresher are shown in the Fig. 3.2.

The crop is threshed in the thresher by the beating action of the cylinder teeth or spikes when the bundle is fed into the feed inlet. The threshed ears and chaff drop into the concave. The threshed grains pass through the concave and are then cleaned by the air blast.

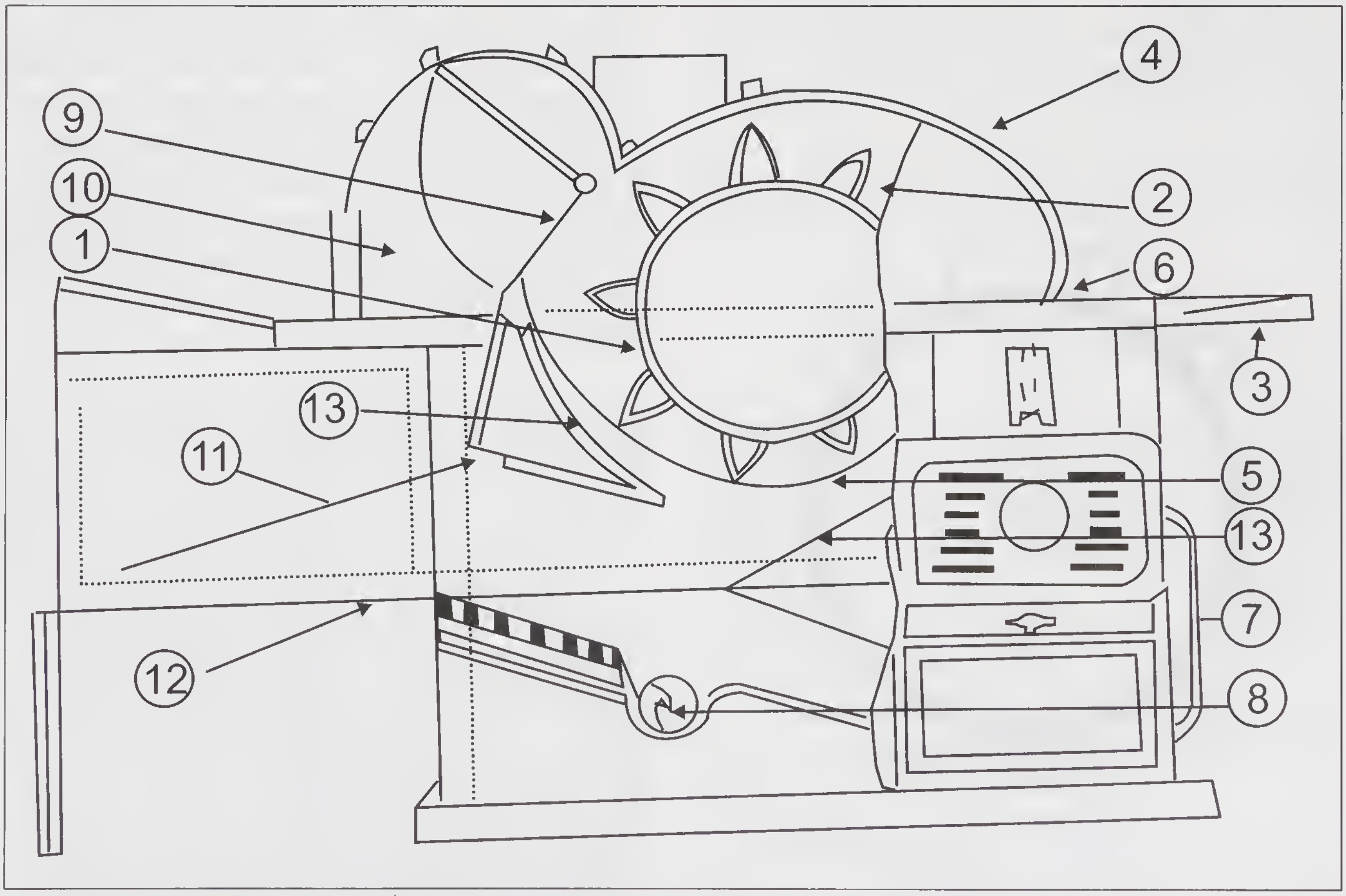

Fig. 3.2. Sectional view of a typical power thresher for rice. 1, Threshing cylinder; 2, Teeth or pegs; 3, Feeding table; 4, Cylinder cover; 5, Concave; 6, Feeding inlet; 7, Fan; 8, Screw conveyor; 9, Chaff discharge gate; 10, Chaff discharge chamber; 11, Straw rake; 12, Immature grain outlet; 13, Slope plate for grain collection.

The clean grain falls into the screw conveyor and is discharged at the grain outlet. The immature seeds are collected at the immature grain outlet. The blower blows the chaff out of the thresher.

Threshing cylinder (Fig. 3.3)

The cylinder is made of sheet of 1.5 mm thickness and the teeth are attached on the peripheral surface of the cylinder. It is mounted on the shaft. The diameter of cylinder is 400 mm. The effective diameter of the cylinder is the diameter of cylinder and the length of one tooth. The speed of cylinder is generally recommended as 600-750 rpm for threshing of paddy crop. As the speed of cylinder is increased above this range, the power requirements and the feed rate of cylinder are increased. The increased speed also increases the threshing efficiency and seed damage. Hence the speed for cylinder is recommended for paddy is 550-600 rpm. The higher speeds are used for threshing of barley.

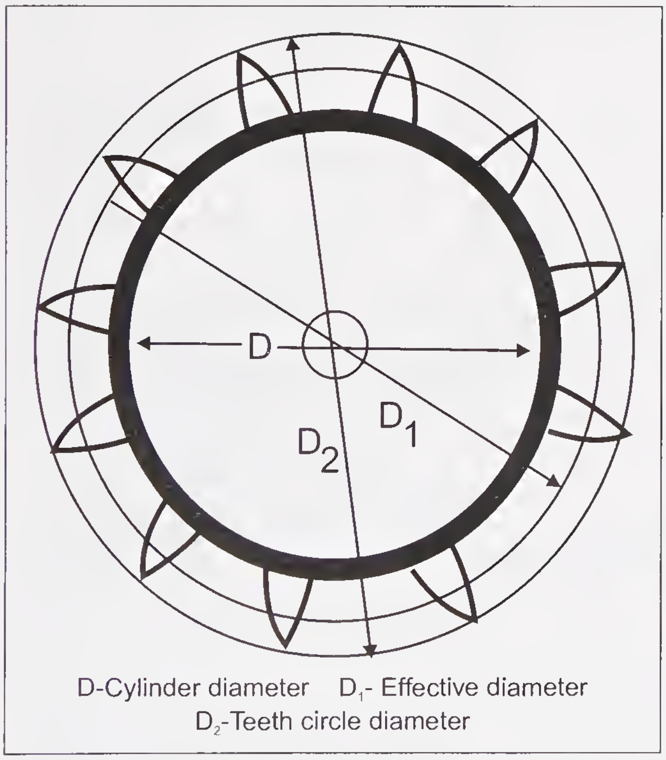

Fig. 3.3. Cross section of threshing cylinder showing different diameters.

The threshing teeth or loops are made of hardened steel wire of 5mm diameter and are given the shape of inverted V or U or semi circular type (Fig.3.4 A-C).

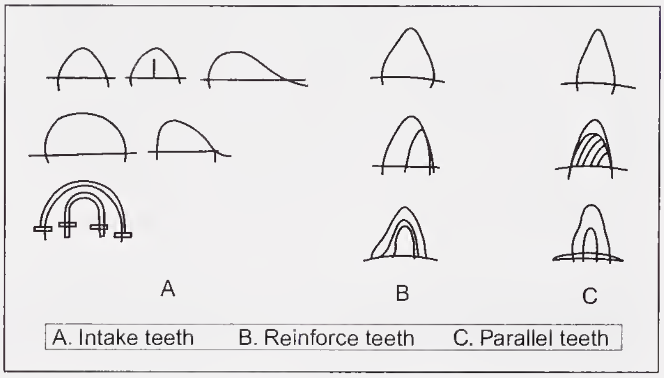

Fig 3.4. (A-C) Types of wire loop teeth used on threshing cylinder for rice crop.

The cylinder teeth at the inlet are known as intake teeth to pull in the crop and spread it thinly. The reinforced teeth are wider than that of parallel teeth. They are mounted perpendicular to the cylinder shaft. The total numbers of teeth on the cylinder are in the range of 80-100 for cylinder of 600 mm length. The teeth on the cylinder are arranged in zigzag fashion, screw type or irregular. The arrangement has effect on threshing action, cutting of ears and the damage to the seed (Fig. 3.5 A-B).

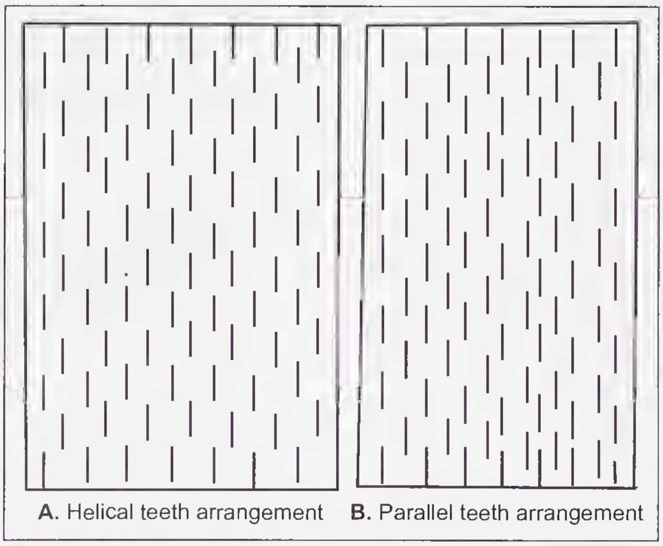

Fig. 3.5. (A-B) Arrangement of wire loop teeth on threshing cylinder.

Concave: The concave is a wire mesh screen surrounding the cylinder. During threshing the grain and chaff falls through the sieve holes and is dropped into an air blast for separation. Concave covers the cylinder by 180 degrees. The concave is made from perforated sheet with 8 mm diameter holes or a wire net, which has the opening of 8x8 or 10x10 mm in size. The perforated sheet has the tendency for retaining the grain for more time and therefore suitable for threshing crops like barley, rye and wheat. The wire net type concave is mostly used for easily threshable crops and causes less of seed damage.

Fan: The fan or blower is of 2 to 4 bladed type, which revolves at 500-1,000 rpm. The speed of two-blade blower is high as compared to three or four bladed fan to provide same value of air velocity. The air speed is controlled by providing the gates at the air intake ends on the sides of the blower.

Chaff outlet gate: The function of the chaff outlet is to keep the cylinder closed from the chaff outlet chamber and when the chaff gets accumulated in the cylinder the gate is opened from time to time by the handle operated lever to discharge the chaff. An automatic discharge operated gate that can discharge the chaff continuously is also provided.

Straw rack: A rack made of steel wires spaced at 20-30mm is positioned under the chaff outlet chamber so that the immature seeds or empty grain go to the tailings chamber and the straw is blown out of the machine.

Conveying device for grain (Fig. 3.6 A–C): The threshed grain is to be conveyed in horizontal and vertical direction by conveyor for lifting and bagging the grains. A screw conveyor conveys the grain horizontally and a blower type fan shifts the grain vertically. The bucket elevator is also used. The volume of grain displaced by auger conveyor is given by simple relationship involving the size and speed of the conveyor.

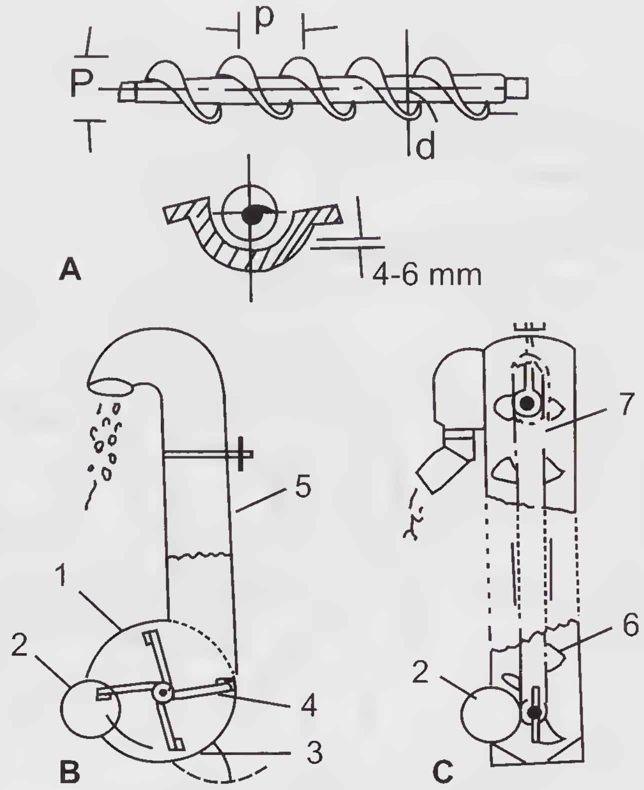

Fig. 3.6. (A-C) Grain conveying devices. 1, Case; 2, Inlet; 3, Checking port; 4, Blade; 5, Flow pipe; 6, Bucket; 7, Belt.

$$Vg = \frac{\pi K.P.N.\ (Da - Ds)^2}{4}$$

Da, outer diameter of the auger (cm); Ds, diameter of the shaft (cm); N, rpm; P, pitch of screw in cm; K, coefficient of conveying (0.5-0.6); Vg, volume of grain conveyed (c.c./ min).

The gap between screw auger and the base plate is kept 4-6 mm (Fig.3.6).

Blower type grain lifter: This type of lifter consists of a four bladed blower with diameter in the range of 250-300 mm revolving at 600-1,000 rpm. The blades impart the acceleration to the grain and the grain is conveyed up through an inclined or vertical pipe to the grain outlet. The grain is then collected in the bag (Fig.3.6).

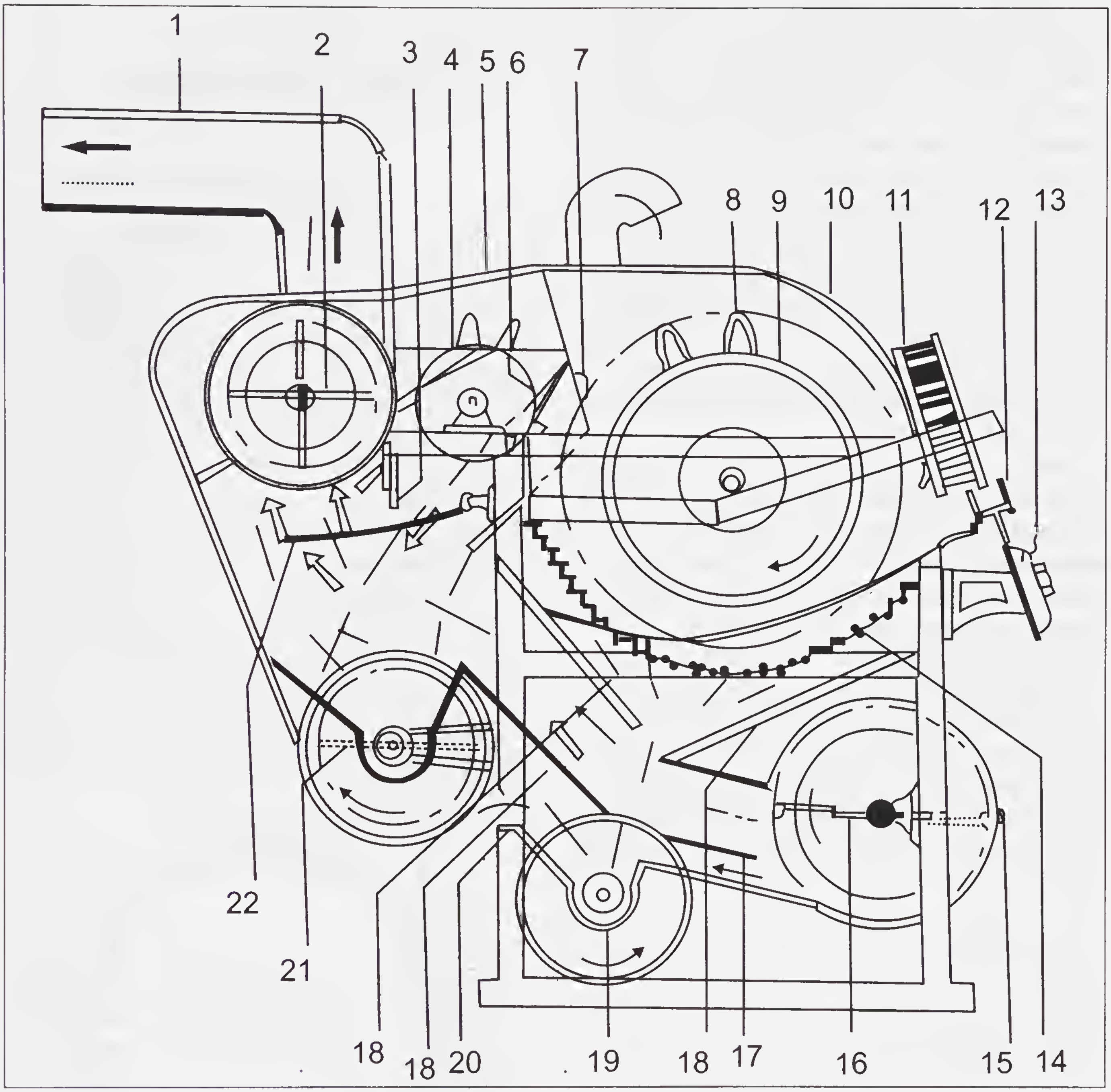

Fig. 3.7. Sectional view of automatic type japanese thresher for rice crop. 1, Pipe for chaff discharge; 2, Suction fan; 3, Dust adjustable plate; 4, Straw beater; 5, Beater cover; 6, Dust adjustable gate; 7, Chaff cutting knife; 8, Threshing tooth; 9, Cylinder; 10, Cylinder cover; 11, Feeding chain; 12, Feeding rail; 13, Compression spring of rail; 14, Concave; 15, Fan cover; 16, Fan; 17, Blast guiding plate; 18, Grain sliding plate; 19, Screw conveyor; 20, Blower air control plate; 21, Tailing thrower; and 22, Spoke type rake.

Japanese automatic thresher

A power thresher when it is fitted with a self-feeding device and some of the function such as control of air blast etc are automated, that machine is called aş automatic thresher (Fig. 3.7).

Self feeding device: The device consists of a crop feeding chain, feeding rail, an auxiliary pipe for holding the crop straw, the compression springs, sprocket and chain drive, which is mounted on the right side of the machine (Fig. 3.8). The bundle of crop is

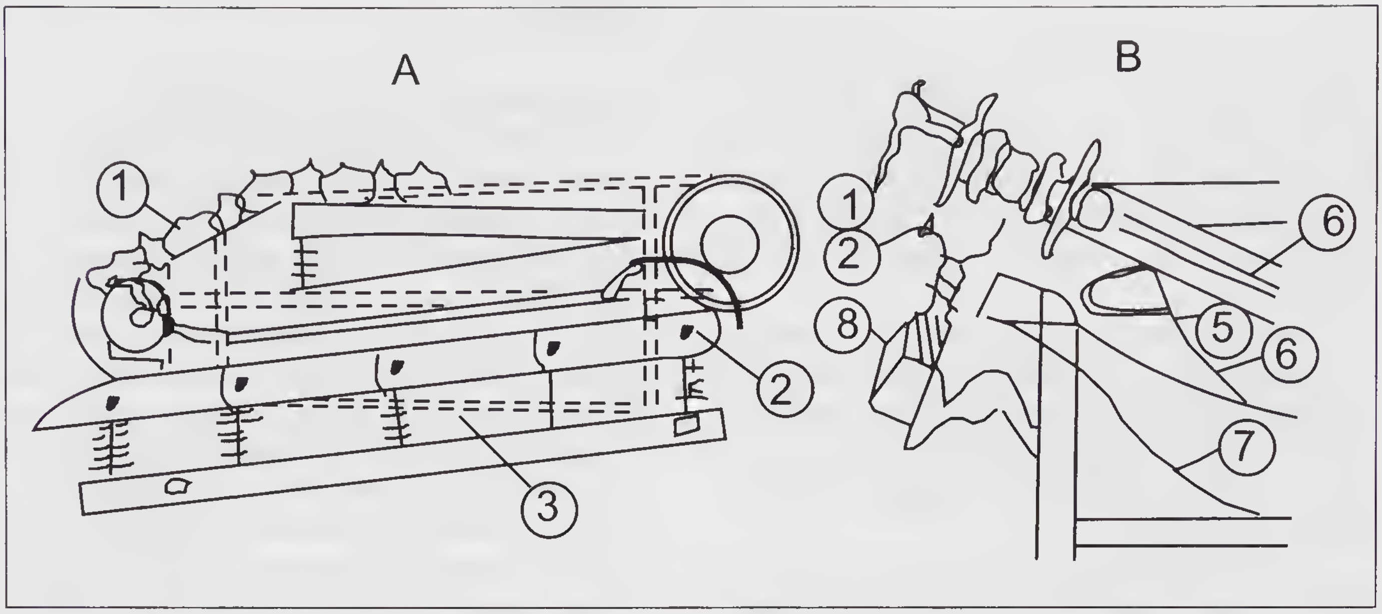

Fig. 3.8 (A-B). Automatic feeding device for feeding the rice crop for thresher. 1, Chain; 2, Rail; 3, Cylinder inlet; 4, Chain shaft; 5, Tooth; 6, Cylinder; 7, Concave; and 8, Spring mount.
(*Source:* Thresher company literature).

fed through the feeding table and the straw is grasped in between the feeding chain and the rail. The bundle is moved along the rail at a slow speed by chain at the speed of 0.25 mps. Therefore, during the 2-3 seconds when the crop is moving through the cylinder inlet the cylinder detaches the grains. The threshed straw is discharged to the right by the straw conveyor. The threshing cylinder is similar to power thresher but with slight modifications. The feeding side of the cylinder is slightly truncated, so as to provide greater space for feeding the straw and for their rearrangement. The intake teeth attached at the truncated portion of cylinder arrange the crop thinly and feed evenly to the cylinder. The teeth arrangement on the cylinder is (i) intake teeth, (ii) reinforced teeth, (iii) parallel teeth, and (iv) shake off plates.

The function of shake off plate is to guide the chaff to straw chamber direct the air blast to the threshed material and thereby help in separation of grain. The clearance between teeth and concave is kept within 3-6 mm.

Tailing device: The thresher is equipped with a device to circulate the unthreshed ears and also the detached ears, which are mixed with the grain and are conveyed by the screw conveyor and the auger.

Straw discharging system: The thresher is fitted with an extra chain conveyor for discharging the threshed straw about 1.0 m away from the machine. It is fitted at the end of the threshing cylinder. This helps less of accumulation of straw close to thresher and allows the worker to remove the straw without disturbing the machine operation.

Automatic air blast control: The cleaning and separation of grain from chaff is achieved by the air blast. The device known is the air speed control lever. The volume of straw bundle being fed into the machine controls the air speed because when the straw is placed on the feeding rail, the feeding rail moves downward due to load and the spring holder pushes the air speed control lever, which is linked to the fan inlet gate. Therefore, if the volume of crop fed is more the speed of the cylinder decreased, however the volume of air will be increased and maintained by the controller. The automatic thresher weight is about 140-160

kg. The cylinder diameter is 360 mm and cylinder width is 400-500 mm. A 5 hp prime-mover operates it as the required power for thresher is 3.50 PS. The output of machine is 1000 - 1200 kg/h with threshing efficiency of 99.5% and with loss of less than 1%. The operating speed of cylinder is 500–550 rpm for rice crop.

The functional layout of an automatic rice thresher (Fig. 3.9) showing the details of the material handled by the different devices. The values are shown as grain and non-grain material values for a 1 tonne capacity thresher with the rice crop.

The values of grain and non grain material values superimposed to indicate the material handled at the different part of the thresher of 1 tonne/h capacity for the crop having grain to non grain ratio of 1: 1.5. Thus it will be noted that the energy input for threshing rice crop are low because of minimum amount of material handled by different units. Further the machine meets the requirements of rice farmers in Japan. However, the cost of imported thresher in India was not viable for the small rice farmers because of low level of productivity.

Development of IRRI rice thresher

At IRRI, Manila, Philippines development of rice thresher for the Asian farmers was taken up during 1966. For this purpose four types of threshing units were selected for conducting trials on rice threshing during 1967. The threshing units selected were (i) rasp bar with concave, (ii) spike tooth with concave, (iii) wire loop cylinder with and without concave for throw in and hold on type threshing. The test stands used for the various threshing systems is shown in Fig. 3.10 (A-D). It was reported that the spike tooth cylinder performs well with hold on and throw in type feeding methods. The threshing efficiency was affected only by 6.7% by the change in cylinder speed from 4.6 to 22.3 (mps) metre per second. The wire loop cylinder also exhibited an excellent performance with the hold on method of feeding (Fig. 3.11). The optimal threshing velocities obtained for paddy with 98% threshing and 1.0% loss and maximum of milled paddy with 85% were as shown in Table 3.2.

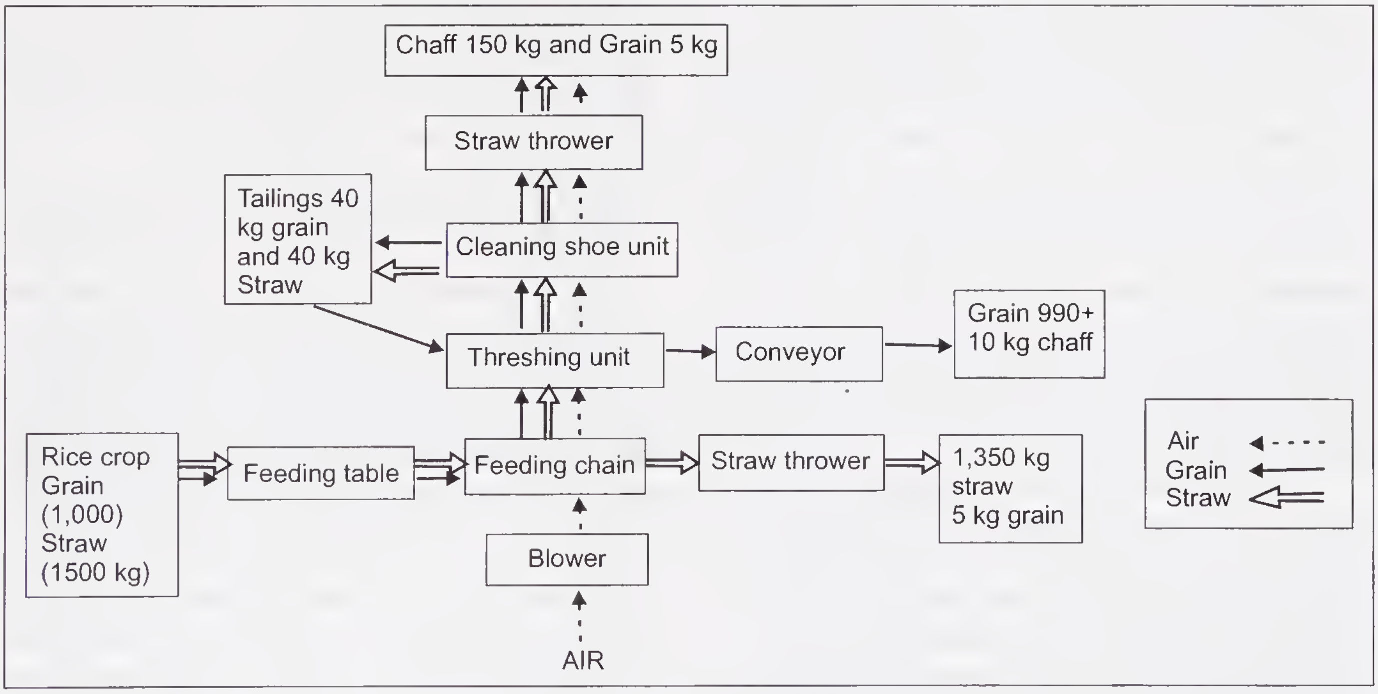

Fig. 3.9. Material flow diagram of automatic Japanese rice thresher of one-tonne capacity.

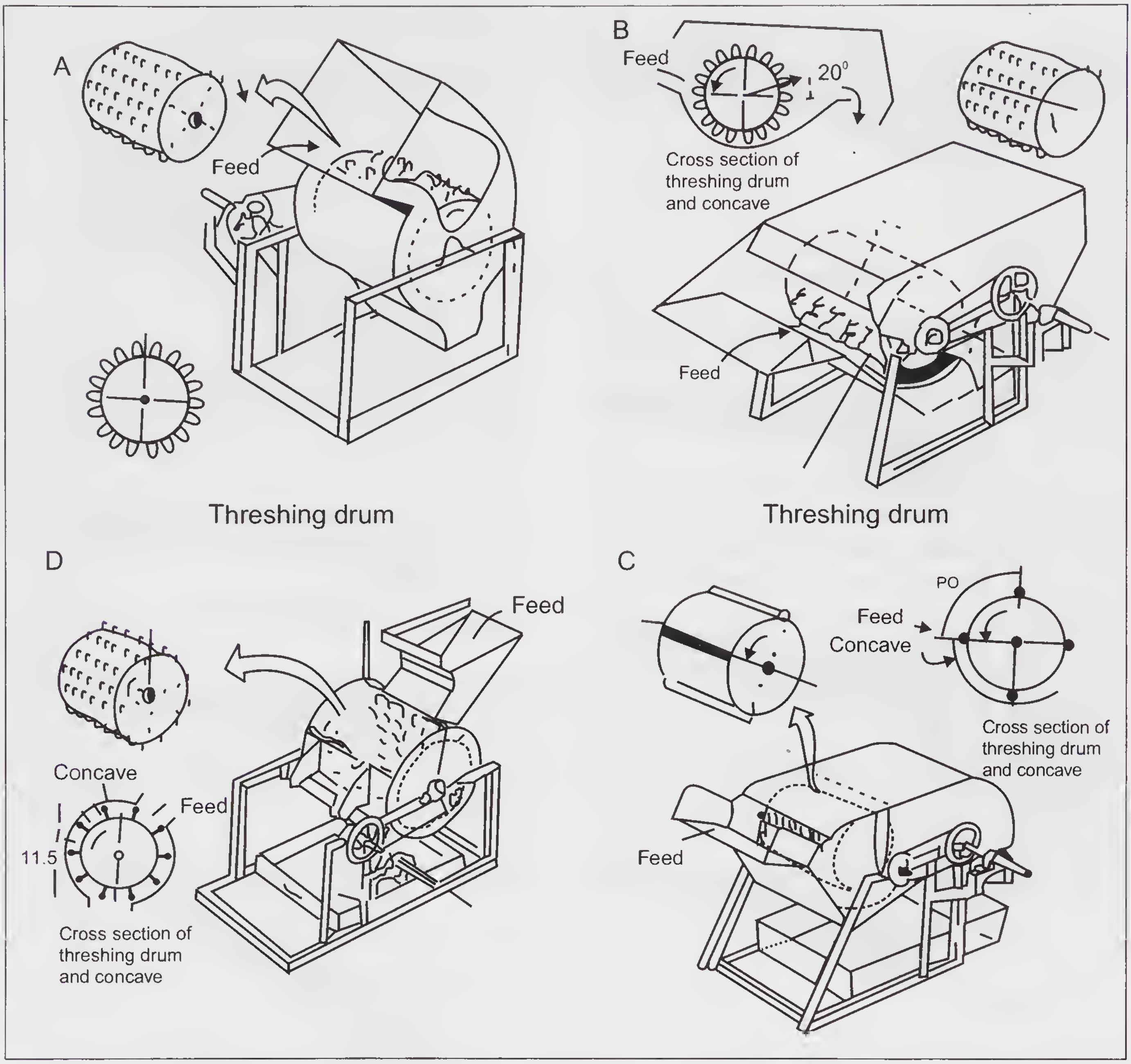

Fig. 3.10. (A-D) Threshing cylinders tests set up for testing on paddy crop at IRRI, Philippines. A. Wire loop threshing cylinder without concave, **B.** Wire loop threshing cylinder with concave, **C.** Rasp bar type cylinder and **D.** Peg tooth type cylinder.

The nine threshers available at IRRI, Manila were evaluated for the performance and the values of the tests are shown in Table 3.3 These included pedal operated thresher, locally manufactured drum type thresher, IRRI drum type, Japanese automatic, Vogel nursery, Garvie type DA rasp bar, etc.

The output of manual method of threshing was 68.64 kg per man-h. The output of threshers varied from 117 to 252 kg/h. The output was highest for IRRI drum type thresher. Japanese automatic thresher had output of 195.36 kg/h. While comparing the labour performance the Japanese thresher had an output of 65.12 kg/h. The IRRI drum type had output of 50.42 kg/h. The output of local drum type thresher and Vogel nursery had output less than manual pedal operated

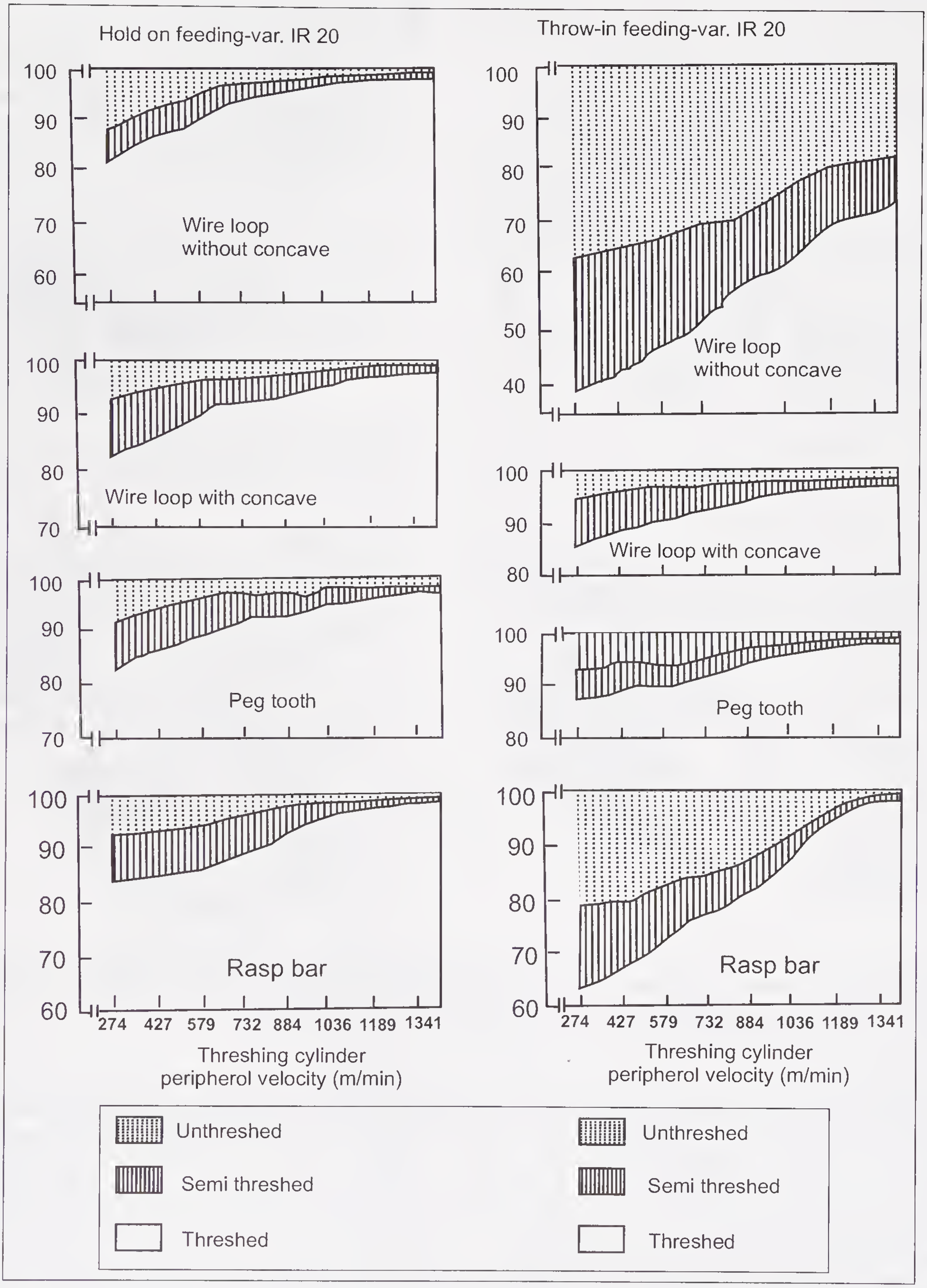

Fig. 3.11. Comparative performances of tested threshing cylinders at various speeds for hold on and throw in method of feeding.

Table 3.2. Threshing cylinders and their speeds for optimum performance on rice

Type of threshing cylinder	Hold on method (mps)	Throw in method (mps)
Wire loop with concave overfed	13.47	19.94*
Wire loop with concave underfed	11.74	14.74
Peg tooth cylinder	11.74	14.74
Rasp bar cylinder	13.47	19.44

*The milled paddy head yield for this was 78.9 and not 85%.

thresher. The Japanese thresher had the disadvantage of high cost and hold on type feeding system. These tests were reported in 1968. Based on these studies and market surveys it was decided to develop a high capacity thresher, which should not be the hold on type. It was concluded that the output of tested threshers were low and of others the power requirements were high. Therefore a thresher with high output and low power requirements was to be developed to make acceptable to the farmers.

Development of axial flow thresher

During the initial period of the developmental work the machines developed

Table 3.3 Comparative performances of selected rice threshers evaluated at IRRI, Los Banos [Laguna (1968)]

Thresher model	Machine performance	Power performance		Labour performance			Economic performance	
	kg/h	Engine Hp-h	Hp per 44kg	No. of men	Man-h per ha	Grain output per man-h (kg)	Machine cost	Threshing cost per 44kg (Pesos)
Pedal thresher wire loop type local make	68.64			2	128.2	34.32	NA	
Single drum wire loop local make	158.40	4.0	1.333	3	83.33	52.80	2464	0.930
IRRI drum type wire loop	252.12	4.2	0.695	5	87.26	50.42	3000	1.06
IRRI table type wire loop	228.80	4.2	0.807	5	96.17	45.76	2500	0.912
Japanese automatic wire loop	195.36	4.2	0.946	3	67.56	65.12	3500	0.765
Drum type locally make spike tooth	117.04	12.5	4.700	4	172.94	29.26	6750	1.512
Vogel nursery spike tooth	126.72	10.0	3.473	4	138.81	31.68	NA	
Turner economy rasp bar type	170.72	10.0	2.577	4	120.00	39.60	NA	
Garvie type DA rasp bar	163.24	17.5	4.717	4	107.85	40.79	NA	

Based on 4,400 kg/ha yield.

(*Source:* Semi-annual Substantive report No.8 and 9 under IRRI-USAID Mechanization Research Contract, IRRI, Philippines)

were hold on type and these were called as Table thresher and Drum thresher. These were evaluated and attempts were made to popularize them. However the market survey indicated that there was a need of high capacity thresher of non-hold on type. The conventional combine harvesters use the through flow method of threshing where the crop passes through rotating cylinder and concave only once along the tangential path. This action subjects the crop to threshing action for the short period only. Because of short period of exposure the crop is threshed with high cylinder speeds which increase the grain damage. The large size straw walkers are used to separate the grain from straw. Therefore the axial flow threshers were developed and tested. The first model developed was the tractor and engine operated axial flow threshers with rotary screen separators. The machine had 4.2 m long threshing cylinder with slightly oval full length concave. The thresher had an output capacity of 1,000 kg/h in wet conditions with threshing loss of less than 1 %. In the IRRI axial flow machine, the material being threshed is to move spirally a few times between the threshing cylinder and the concave while it moves quickly along the axis of the threshing cylinder.

The spirally mounted louvers in the threshing cover move the material along the axial direction (Fig. 3.12). This provides a long threshing exposure; permitting the versatile threshing action where most of the grain separation takes place and the threshing cylinder speeds are low.

This type of machine causes less damage to the grain and works well in wet crop conditions. As the grain is separated from straw while being threshed there is no need to use straw walkers. Thus, the machine becomes more compact as compared to conventional threshers with same output. This thresher was called the IRRI model TH.3.

The machines developed were high capacity threshers meeting the technical requirements but were suitable for very large land owners. It was beyond the purchasing

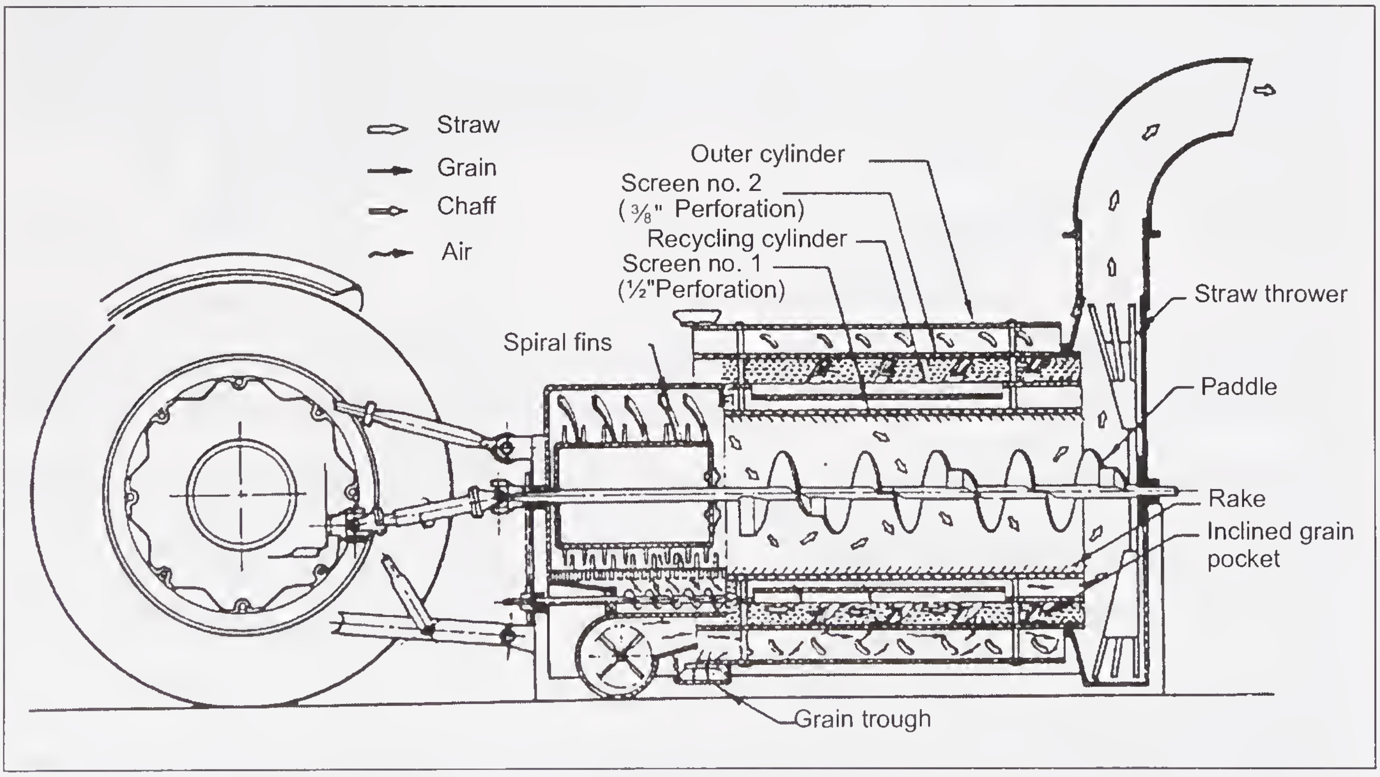

Fig. 3.12. Sectional view of IRRI tractor p.t.o driven axial flow thresher (IRRI Reports).

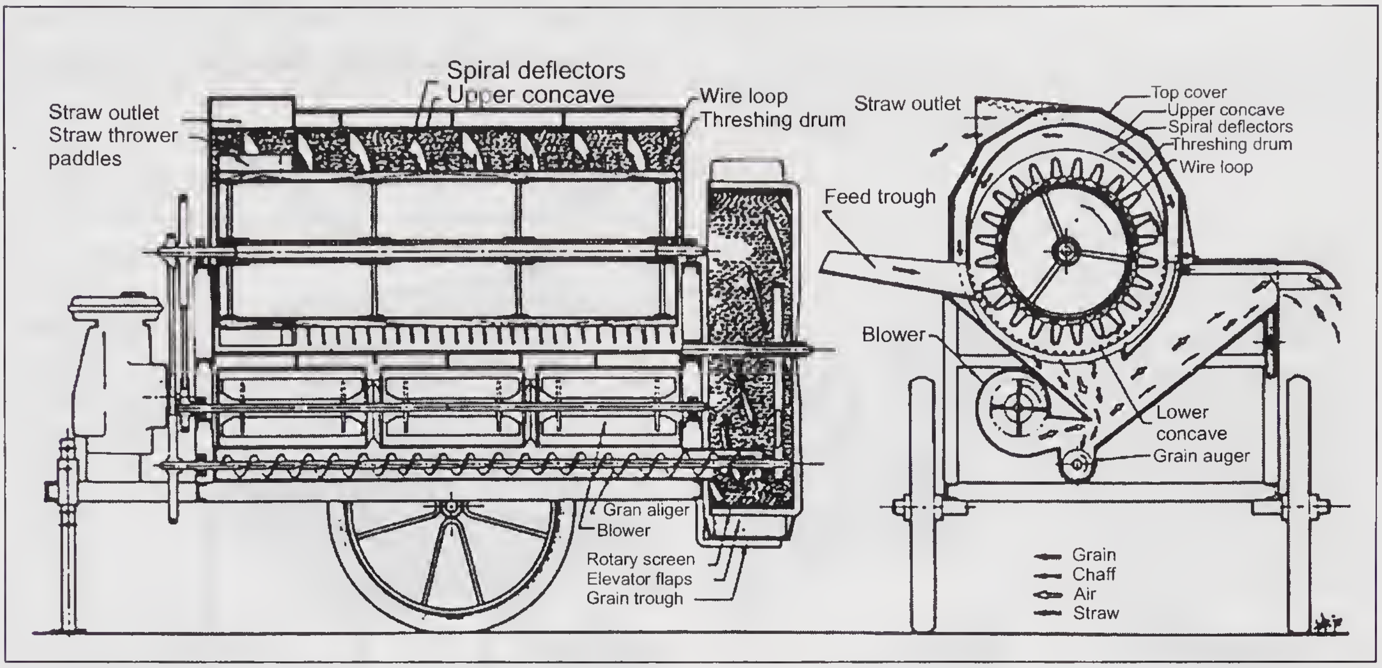

Fig. 3.13. IRRI axial flow thresher with rotary screen cleaner operated by engine.

capacity of small farm holders. Therefore new specifications were set for the development of thresher for the small farm holders.

Development of axial flow thresher TH-6: The aim was to develop a simple lightweight axial flow thresher having weight not to exceed 100 kg and price to be about $ 500.00. The design was taken up according to specifications planned for the product. The design consisted of 420 mm diameter drum of 710 mm length with concave screen area of 0.42 square metres. The concave of wire mesh and round rods were tried both gave acceptable results. The upper concave was made from the sheet metal rather than rod type grill used on earlier models. This change in design reduced the screen area by 22% of earlier design. The separation and unthreshed material at initial stages were high. Decreasing the gap between cylinder and concave, providing stripper bars at the inlet section and adjusting the louver angle reduced the unthreshed and separation efficiency. A louver angle of 6.5 degree was selected for the final design of the portable model thresher (Fig. 3.14).

The threshing studies indicated that where crop variety had long length and hard to thresh, there was need to use the stripper bars to prevent wrapping of straw on the threshing drum. As the thresher does more aggressive threshing due to use of strippers they reduced the capacity of thresher per horsepower. In case of mature crop if the strippers are used they increase the amount of non-grain material passing through the concave.

Hence strippers are used whenever they are essential. The unit under field conditions gave output of 400 kg/h compared to 500 kg/h capacity with axial flow unit. Even this low cost thresher the break-even point for the thresher was 36 tonnes of crops. Thus with a yield level of 4 tonnes/ha with two crops per year required a minimum of 4.7 ha holding. With this thresher the labour output was double as compared to traditional method of threshing.

IRRI threshers with cleaning units: The thresher models Th-7 and TH-8 designs were developed to incorporate cleaning system and on TH-8 it was mounted on wheels. These machines were high capacity varying from 400-1,000 kg/h to meet the requirement of large farmers and doing custom work in Asian countries. These were popularized in

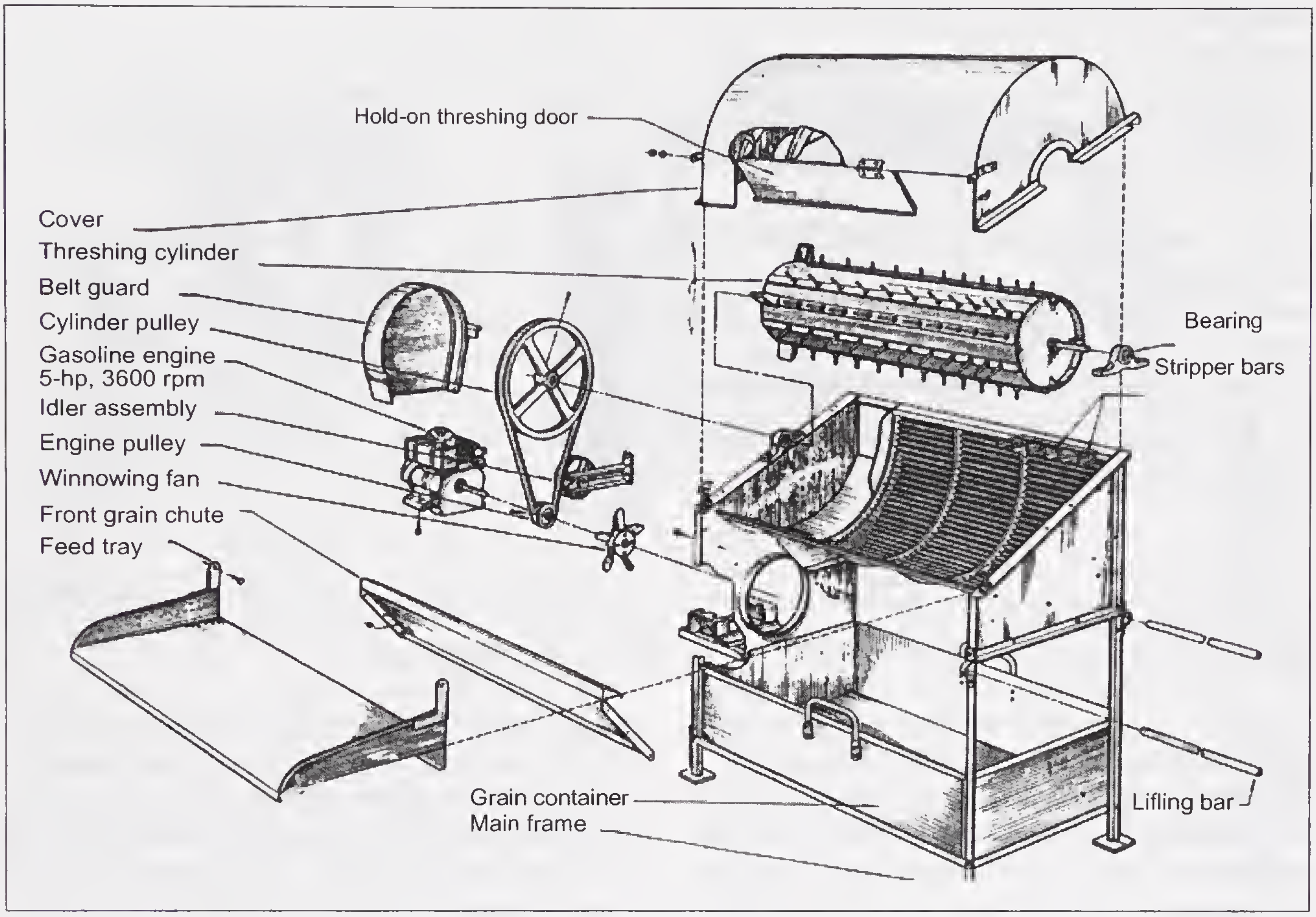

Fig. 3.14. Exploded drawing of IRRI portable thresher TH-6.

Thailand, Malaysia, Indonesia, India and Pakistan and a few other countries. The design details of TH-7 and TH-8 threshers are given in Table 3.4 and schematic diagram is shown in Fig. 3.15 (A-B).

Some modifications were carried out on IRRI threshers for threshing of sorghum. This involved modification on threshing cylinder and concave etc. Thus the successful thresher was developed for most of the Asian countries.

Studies on threshing drums and concave for rice at IRRI (1987)

It was concluded by Sakun (1963) in Japan that the wire loop type cylinders have higher threshing efficiency and performance and also used 23.4% less fuel than the rasp bar type cylinders. This was further studied by Sarwar and Khan (1987) where the performance of threshing cylinders for rice crop in terms of cylinder speed, concave clearance, feed rate and grain moisture content for the identical cylinders of 444.5mm diameter and 508 mm length were reported. The rasp bar cylinder had four bars and wire loop cylinder was fitted with 47.3 mm loops at 51 mm spacing on the rows. Feeding of crop was by means of conveyor belt 3.66 mm long and 588.8 mm wide. The cylinders were operated by a 10 hp motor. The crop moisture levels were 16 and 24 % (wet basis). Three concave clearances of 3.1, 6.3, 9.5 mm and two feed rates of 120 g/s and 240 g/sec were selected.

The tests conducted at 16% moisture level indicated that for feed rate of 240 g/s the wire loop cylinder gave higher threshing

Table 3.4 The specifications and critical clearances for three IRRI threshers

Particulars	Portable	IRRI TH-7	IRRI TH-8
Type	throw in axial flow	throw in axial flow	throw in axial flow
Crops	rice and sorghum	rice	rice
Labour requirements	2-3	3-4	3-4
Power requirements (hp)	5	10	7
Dimensions in mm			
Length	950	1,190	1,900
Width	700	1,320	1,500
Height	1,300	1,590	1,780
Construction	all steel	all steel	all steel
Weight (kg)	105	190	465
Cylinder type	spike tooth	open spike tooth	open spike tooth
Diameter	305	305	394
Length	711	710	1,110
Speed rpm.	600-630	600-650	540-600
Speed metre/s	12.5	12.5	14.5
Louver angle degree	6.5	6.5	6.5
No. of rows of teeth	8	8	8
No of teeth	88	88	-
Concave area sq.m.	0.43	0.43	0.84
Concave clearance mm	25.4	25.4	25.4
Concave material	round bar/wire mesh	round bar	round bar
Cleaning system	air blower	air blower with screen	blower with screen
Adjustments	--	blower shutter and angle of wind board	blower shutter/ angle of wind board
Stroke length of oscillating cam in mm	----	9.6	9.6
Stroke length of oscillating screen		31.8	31.8
Screen hanger inclination from vert.		25	25
Blower type		four bladed	four bladed
Speed of blower		750-800	750-800
Clearance between blade and housing mm		3.2	3.2
Blower air velocity		427	427
At wind board mpm		349-351	349-351
Auger and housing clearance in mm		4.8	4.8
Clearance between straw thrower paddle and sheet	1.6	1.6	1.6
Capacity paddy in kg/h	up to 600	450 to 500	800-1000
Threshing efficiency %	98	98	98
Grain breakage %	less than 2	< 4	< 4
Specific capacity kg/hp	110	50	110-140
Separation capacity of concave kg/h sq.m.	1,350	----	----
Sorghum capacity kg/hp	200	-----	----

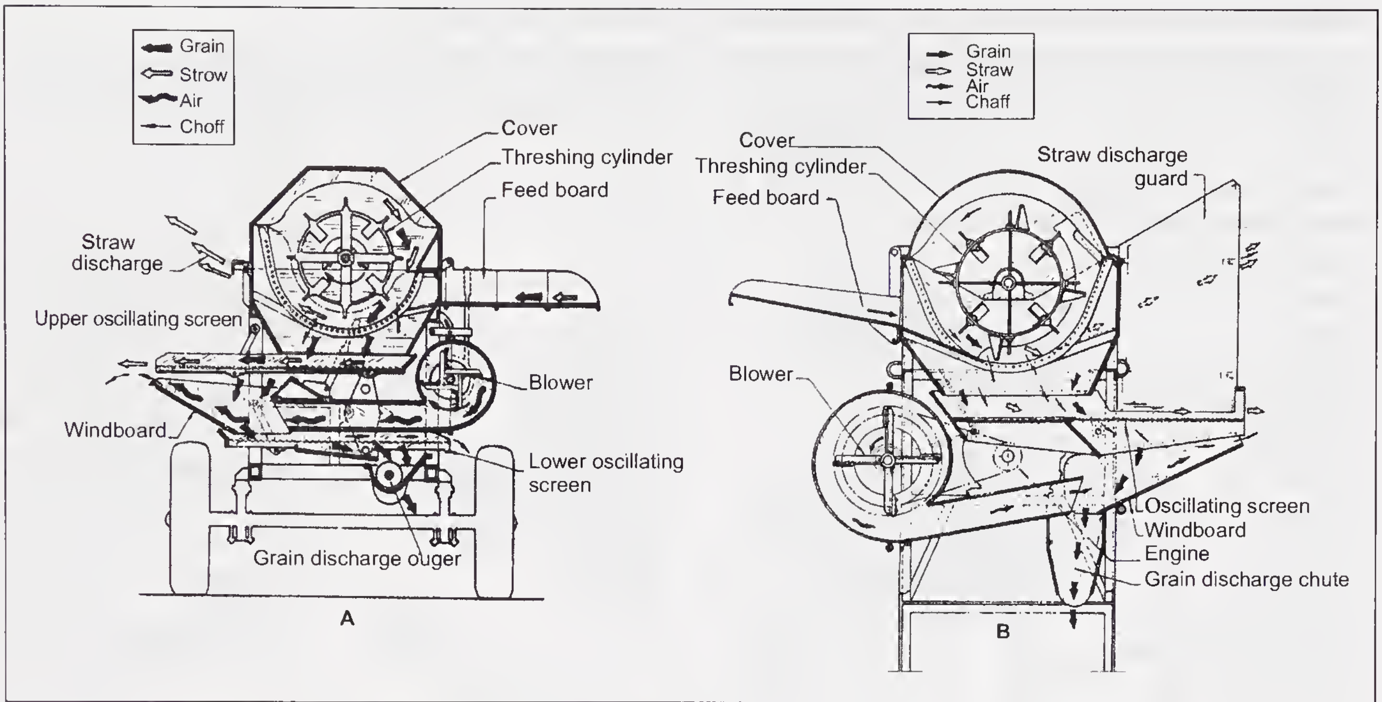

Fig. 3.15. (A-B) Sectional view of IRRI thresher model TH-7 (A) and TH-8 (B).

efficiency at lower speeds and after 18.64 m/s speed the performance in terms of threshing efficiency improved but at the same time the per cent of husked grain also increased. At low feed rate and 3.1 mm concave clearance the performance was the same. At 6.6 mm clearance the performance of wire loop was better but as the speed increased beyond 15.97 m/s the performance peg tooth cylinder improved. The percentage of husked grain was more for rasp bar threshing cylinder as speed increased and at all concave clearances.

For tests performed at 24% moisture level performance of two drums was same for low feed rate, low concave clearances. At clearance of 9.5 mm the wire loop cylinder gave better performance. It was better from speed from 13.66 m/s to 18.63 m/s. The rasp bar performance improved above those speeds. For wire loop cylinder no grain damage up to cylinder speed of 18.63m/s was noticed. The damage of grain started at speed of 18.63 m/s when the clearance was 9.5 mm. It was concluded that wire loop type threshing cylinder was more compatible for threshing of rice crop.

IRRI axial flow thresher for multi-crops

Singhal and Thierstein (1987) evaluated the IRRI axial flow thresher with cleaning system used to thresh the crops like sorghum, pigeon pea, chickpea, millets and wheat. The thresher performance on paddy indicated that it had a capacity of 1000 kg/h with 1.5% blower loss and cleaning efficiency of 99%. It has peg tooth type cylinder with semi hexagonal cover. The performance of thresher on chickpea and pigeon pea was good. The crops were threshed at 9 to 10 % moisture level with capacity from 300 to 500 kg/h.

When it was used for threshing sorghum ears (CSH-86) at cylinder speed of 13 mps the threshing efficiency was 36% and for millet (BJ-104) the threshing efficiency was 36 % and output of 250 kg/h. To improve performance the changes were made in the threshing cylinder by attaching the flat belt for 1/3 of cylinder length and covering the concave with wire mesh for 1/3 the length. This helped in improving the output and threshing efficiency of the machine up to 88%. The performance also improved for millet but it was unsuitable for pigeon pea. Thus to make thresher

multicrop the modifications were carried out in cylinder speed, cylinder configuration, concave partially blanked, blower speed increase and cleaning sieves changed for the different crops. In spite of increasing the speed of blower the cleaning efficiency was low. They suggested the sieve sizes for cleaning the different crops (Table 3.5).

The study concluded that axial flow paddy thresher could be multicrop by making necessary modifications in the threshing and cleaning units.

Table 3.5. Recommended sieves for use on thresher for threshing other crops

Crop	Sieve top hole size in mm	Sieve II hole size in mm
Paddy	8	6
Sorghum (CSH-6)	6	4
Millet (BJ-104)	6	2
Pigeon pea	6	4
Chickpea	6	4

Development of rice threshers in India

The development and commercialization of rice threshing started during 1956-57. At this time a few threshers were imported from Japan. These were pedal and power operated and also automatic type units. These were introduced in the country primarily for their evaluations in rice growing regions. The big stationary type threshers were also imported from European countries and USA for use on big farms and government and state farms for use in state of Bengal, Tamil Nadu and Andhra Pradesh for threshing of rice crop. These were fitted with rasp bar and peg type threshing units and fitted with straw walkers and cleaning shoe. The thresher threshed the crop and delivered clean grain and also was fitted with straw blower for blowing out the straw away from the machine with the help of straw blower. The schematic diagram of the McCormick Deering power thresher as used in past is shown in Fig. 3.16. These machines were large and required skilled operators to

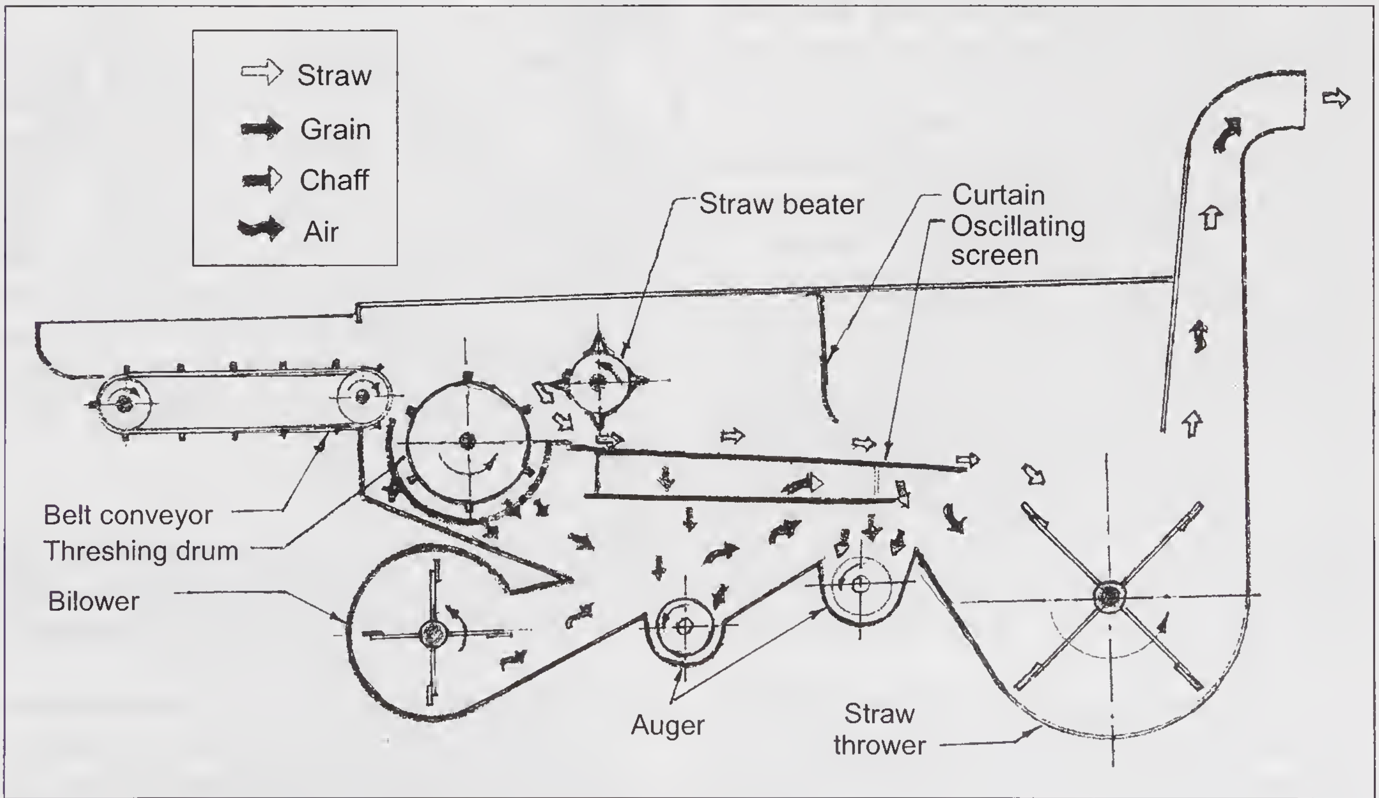

Fig. 3.16. Schematic diagram of McCormick Deering Thresher.

operate them and were also of high capacity making them uneconomical for the small farm holders.

One company in India produced and marketed pedal operated Paddy Thresher during 1960 based on Japanese design. It was pedal operated type with gear drive arrangement to speed up the rotation of wire loop type threshing drum.

Fenn (1967) presented paper on paddy threshing in Kerala. He reported that the most common method of threshing was the trampling by labour on the crop spread on threshing floor. The labour was paid in terms of grain threshed for the operations of harvesting and threshing. The labour payment was in kind which was equal to 10 % of the grain yield. The trampling by animals, trampling by roller and also threshing by pedal thresher was practiced in few parts of kerela.

The pedal thresher effectively threshed the new varieties of rice. The main disadvantage was the high cost of machine. The cost was only ₹ 250 (US $ 45) per thresher. However it was further reported that as straw was not trampled, the straw produced by pedal thresher was unpalatable to cattle.

Pradhan (1969) in his studies on evaluation of different methods of threshing rice crop at Cuttack, reported that the output of grain by tractor treading method was high per day as compared to other methods. The use of tractor for threshing purpose was found to be more expensive in comparison to other practices. The cost of threshing with tractor and six labours was ₹ 11.52 (US$ 1.5) per hour. The use of power thresher added to the convenience, quality and saving of bullock power even though the output and cost of threshing are more or less the same as threshing by traditional methods.

Developments in India during 1969-76: "Yanmar" power thresher from Japan gave the best performance in terms of grain output in 1969. The thresher was fitted with two drums type threshing unit, powered by 5 hp electric motor and had an output of 550 kg/h. The output of plot thresher was low as compared to Japanese threshers. But it was compact and simple in design which was appreciated by the farmers.

Further the performance values of 25 threshers manufactured locally were reported. These threshers were for threshing of wheat, paddy, sorghum, pearl millet etc. It was reported among the threshers evaluated "Hira Thresher" was given the Certificate of Merit by ICAR, New Delhi as it had the lowest cost of threshing of ₹ 6.50 (US$ 0.85) per tonne of grain output. The Pusa –20 thresher developed by research engineer at IARI, New Delhi was able to thresh the wheat and paddy crops satisfactorily. Therefore it was recommended for the farmers to increase the use of multicrop thresher for threshing the two crops thus reducing the fixed cost of machine for the farmers. In 1970 the development of Pusa-40, thresher, Rice wheat thresher at PAU, Ludhiana, and Allahabad thresher for paddy were reported.

Jacobi (1974) working at Cuttack, India, under the program of Rice Mechanization of FAO evaluated threshing and harvesting machines for rice crop at Central Rice Research Institute (CRRI) at Cuttack. The thresher evaluated included pedal operated rice thresher, Allahabad thresher, Pusa –40 thresher, Vicon ST-70 combine (tractor side mounted type), four wheel tractor treading and Iseki HD650 combine harvester (self propelled with tracks).

He concluded that:

(i) The pedal operated thresher has no advantage of savings in the labour. This means the output of thresher was same as that by the traditional method.
(ii) Allahabad and Pusa-40 threshers were able to thresh the rice crop, as both were pass through type threshers.
(iii) The threshing capacity of tractor

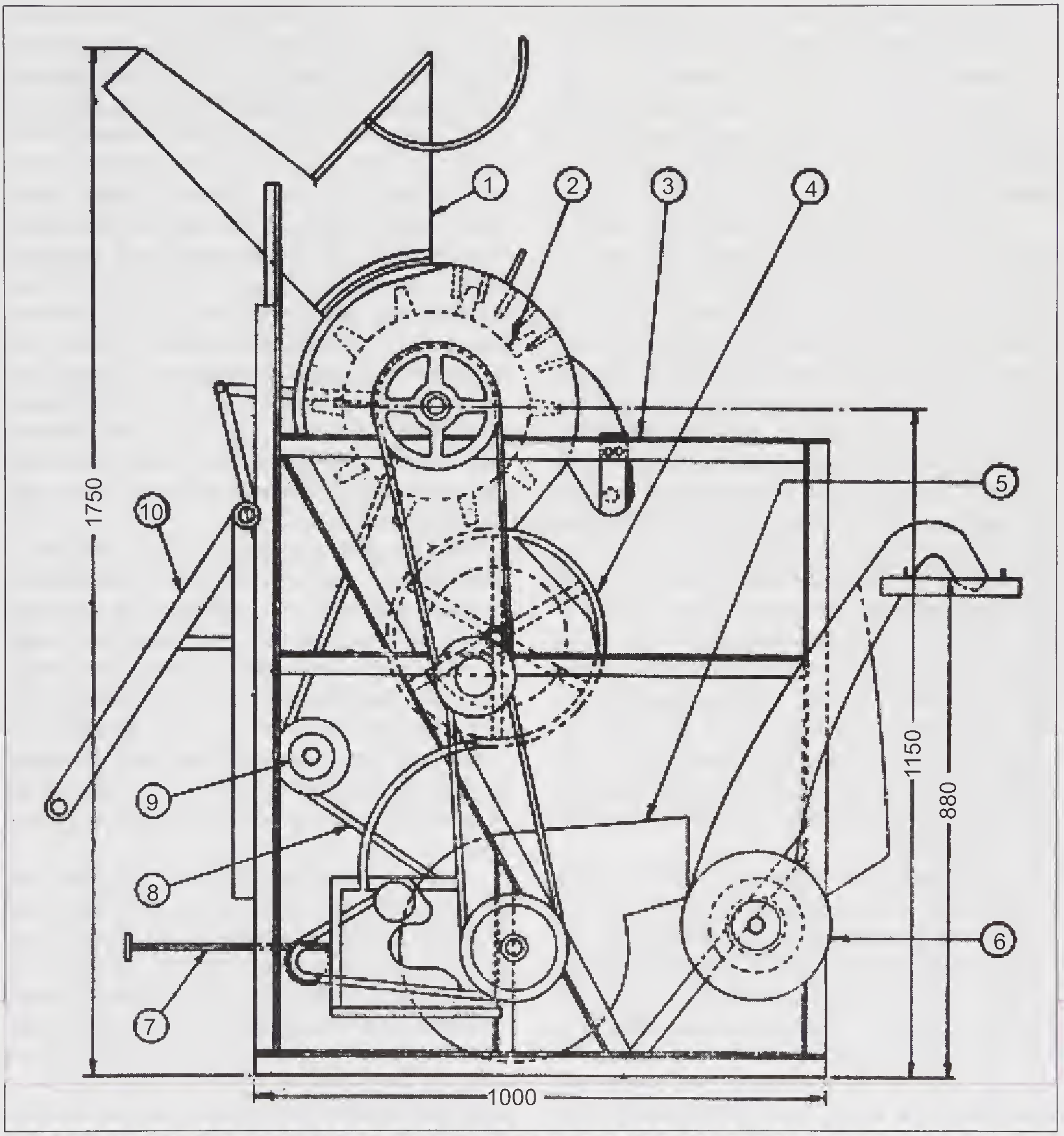

Fig. 3.17. Schematic diagram of Pusa-40 thresher developed for paddy and other crops. 1, Feed hopper; 2, Threshing drum; 3, Frame; 4, Beater drum; 5, Blower; 6, Grain blower; 7, Air flow control; 8, Belt drive; 9, Shaker; and 10, hitch.

treading of four wheel 35 hp size was 500 to 690 kg/h, and this output was less as compared to the use of tractor for operating the thresher.

(iv) The high capacity threshers can be used mainly for custom hiring purpose.

(v) Considering the economic frame of Indian rice region, the combine harvester

of Japanese type was not recommended.

(vi) The medium capacity thresher would meet the demand of the farmers.

Thus for the small rice farm holder manually operated thresher was the machine recommended and this had no advantage in terms of work output.

At this time the rice threshing was not considered of economic benefit because of not only availability of thresher but also the financial capacity of rice farmer to pay for owning the machine and his capacity to use it on the farm for personal work and custom hiring. The need for undamaged straw for the farmers made thresher as non-essential. Only a hold on type thresher was acceptable as it left the straw in desired form for use as animal feed and for thatching their homes. Thus pedal operated thresher was acceptable for many farmers. With the improvement in crop yield levels the need of low cost winnower was also felt. Thus the thresher, which was a threshing drum with wire loop type spikes and powered by a small electric motor was acceptable. The size of power unit was of 0.5 hp size was acceptable as it could be operated on single-phase power. It was needed, as power supply was never assured in the rural areas especially in rice regions.

A committee appointed by 'Ford Foundation' to evaluate the status of rice processing in India during 1966-68, it was recommended that the modernization of rice milling industry would be highly desirable. Beside that the harvesting and threshing technologies being adopted by the rice farmers should also be modernized. The team had concluded the study and recommended the following measures to be adopted.

i) To harvest rice crop at appropriate moisture so that shattering losses are minimized.

ii) To use modern rice mills so that milling losses are minimized and,

iii) To use modern parboiling systems so that higher milling recovery can be obtained.

These recommendations were based on studies conducted at Indian Institute of Technology Kharagpur, CFTRI, Mysore and other places. By the end of 1970 sufficient data could be generated so that the modernization of harvest and post harvest operations could be recommended on scientific basis. India was facing at that time about 10% deficits of food grains. The study conducted at Indian Institute of Technology, Kharagpur, India showed the grain recovery of rice crop by harvesting at proper moisture level and drying the grain by mechanical dryers can make surplus in food grains. The results are presented in the Fig. 3.18. Thus to have high grain output the rice, the crop was to be harvested at higher moisture level and threshed mechanically.

However to implement the recommendation was not easy as it involved the millions of small rice farmers producing grain. Even it was difficult for them to harvest the crop at high moisture level because they were using the traditional hand tools. However the importance to reduce the pre- and post-harvest losses was greatly emphasized and the scope of post-harvest mechanization of rice milling was greatly understood due to results of these studies.

Thus development of an appropriate rice thresher for the developing countries was a great challenge, especially for the farmers growing rice crop on small land holding and performing sustainable type of farming having a labour wage rates of less than one US $ a day. The crop yield levels of resource poor farmers were in the range of 1,100 to 1,400 kg/ha, it was not feasible for them to own a thresher for threshing of the rice crop. It was with the introduction of high yielding varieties, use of chemical fertilizer and irrigation, which helped the farmers to increase the yield levels by 100% and more. Thus the need of threshers was greatly felt in rice regions by the end of eighties. At this time the thresher designs were improved and suitable machines were

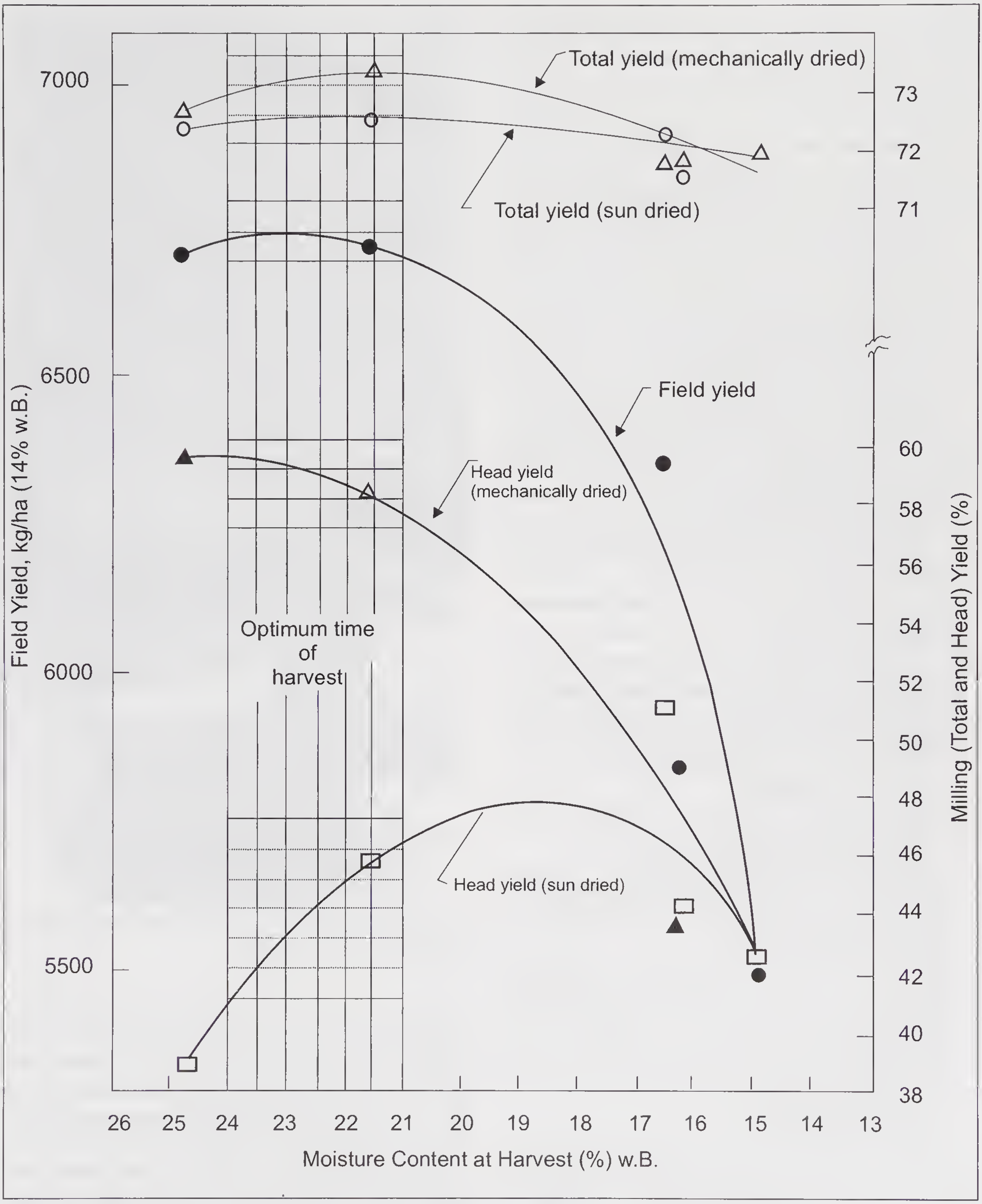

Fig. 3.18. Effect of grain moisture content at time of harvest on milling recovery of IR-8 Paddy.

available for all farmers and situations in rice growing countries.

Threshers available for:

Small farmers

- Pedal operated wire loop type thresher (Fig. 3.19),
- Power operated wire loop thresher ½ hp electric motorized unit for hold on type threshing,
- Rasp bar type thresher with concave without cleaning system, and
- Power operated wire loop drum type thresher for two workers,

With these machines the farmers utilized simple winnowing fans or scalper type cleaner with slot type screen,

Medium scale farmers

- IRRI axial flow thresher model T-6/T-7 (Fig. 3.19),
- Japanese type power thresher with hold on type feeding,
- Japanese type threshers with throw in type feeding and cleaning with blower, and
- Spike tooth axial flow thresher with improved cleaning system, and

Large farm holders

- High capacity axial flow thresher with cleaning system (IRRI design),
- Axial flow multi crop threshers developed at (PAU Ludhiana/ GBPUAT, Pantnagar/ CIAE, Bhopal), and
- Rasp bar type threshing cylinder with straw walker and cleaning shoe commercial machines produced in Hyderabad, Madras and at CIAE- IRRI Industrial Extension unit located at Coimbatore India.

Thus threshers with output of 40 kg/h to 1,400 kg/h operated by ½ hp to 10 hp size electric motors were produced and marketed during 1980-85. With the development of combine harvesters, the crop in rice

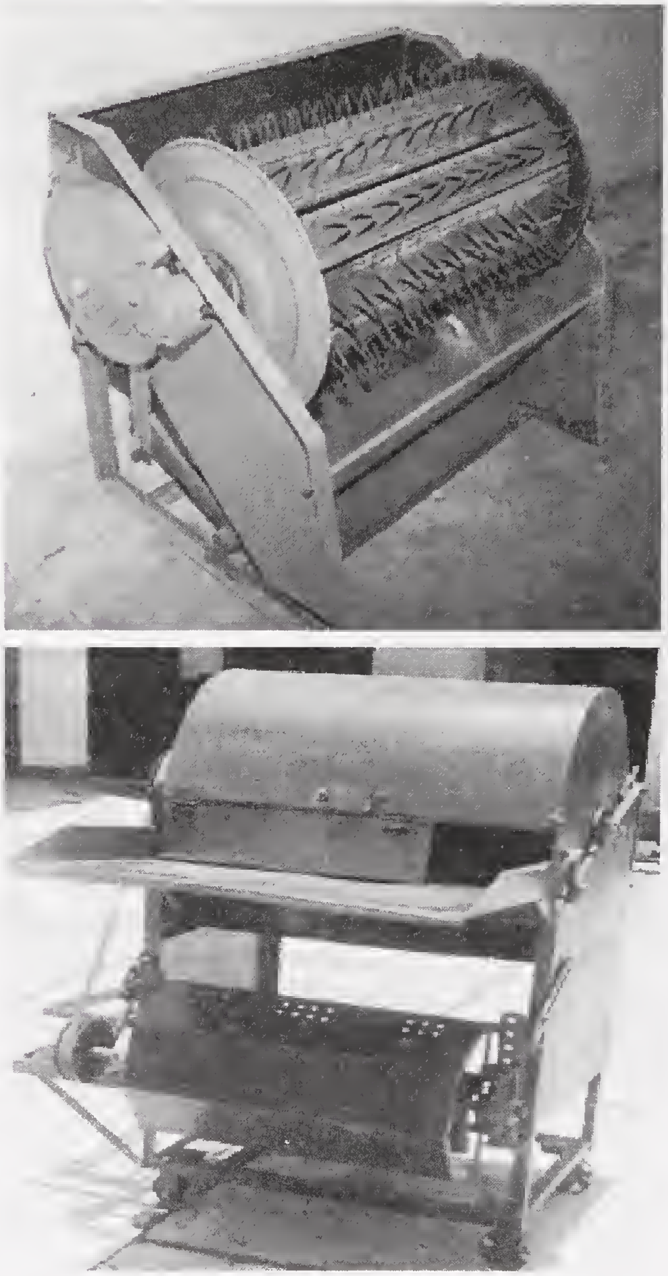

Fig. 3.19. Commercial units of pedal and IRRI axial flow portable rice threshers.

regions of Punjab is harvested with combine harvesters. These machines used spike tooth type threshing drum for threshing the crop. The 4-5 m wide machines can handle 2.5 tonnes/h of grain. These machines are widely used by farmers on the basis of custom hiring in large numbers in India. Thus, there are threshing machines for all categories of rice farmers.

In future rice will be grown only in

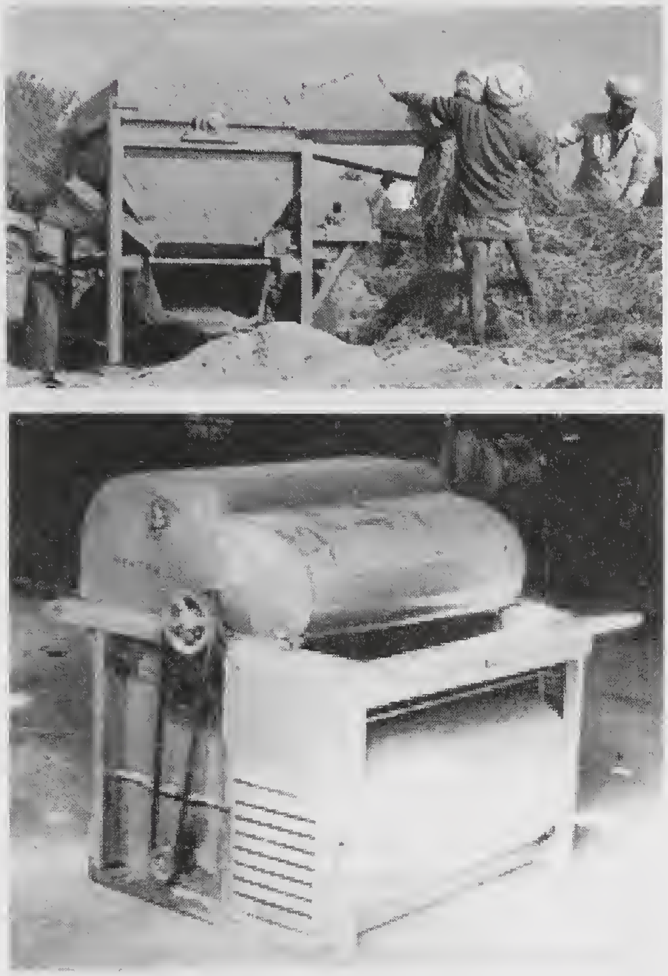

Fig. 3.20. PAU axial flow rice thresher and commercial rice thresher with wire loop drum used in Islamic Republic of Iran (*Source:* RNAM Catalogue 1991).

traditional high rainfall areas because of high water requirements of rice crop and in these regions the farmers have small farm holdings. Unless their size of farm holdings is increased, the need of small threshers will be the main requirements in rice regions of Asian countries. To achieve the full potential of yield of rice crop the harvesting of crop at optimum moisture level is very important. Harvesting of crop at optimum level, which is above 22% moisture level and mechanical drying of rice after it is threshed, the head yield recovery of about 66-70% of rice can be achieved. Thus mechanized approach to rice crop harvesting and post harvest technology would be responsible for at least 5-6% of more and better quality grain to the farmers. With land holding size between 0.2 to 0.4 ha and yield potential of 6-7 tonnes/ha the rice farmers would be practicing sustainable type of farming. The big machines (Fig. 3.20) can be useful only for commercial production of rice which is practiced on large farms 7 tonnes/ha the rice farmers would be practicing sustainable type of farming. The big machines (Fig. 3.20) can be useful only for commercial production of rice which is practiced on large farms.

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4 Radial Flow or Hammer Mill Type Wheat Threshers

Animal operated thresher 40
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High capacity thresher 52

The threshing of wheat crop by traditional method in the past was a labour intensive operation, as it involved 19 man-days and 7 bullock pair hours for threshing of 2 to 3 tonnes yield level of crop per hectare. It further involved the winnowing for cleaning of the grain. The cleaning operation was carried out in the natural wind or by using large size fan. The development of wheat thresher in India during 1955-56 was the timely activity to mechanize the threshing operation in wheat growing region of Punjab. The conventional American and European machines imported in the early 1940-45 were costly and huge in size and did not make the straw in the bruised form as it was to be utilized as animal feed. The cost of imported threshers was beyond the reach of small-scale farmers of India.

In India after independence in 1947, the agricultural development was given the top priority to meet the food requirement of growing population of the country. During the same period a number of irrigation projects were also taken up which resulted in increase in food production. The efforts were made to modernize and mechanize the agriculture. To meet the farmer's demand, the first indigenous bullock operated thresher was developed at Allahabad Agricultural Institute, Naini, Allahabad and was known as Olpad thresher (Fig. 4.1).

Animal operated thresher

Olpad thresher consists of 20 circular disks each of 45 cm in diameter and 3 mm thick placed 15 cm apart in three rows. An angle iron frame is provided to support the three gangs of discs. A wooden platform is provided as the operator's seat. Steel wire mesh is fixed on the machine to make it safe and guard against the serrated edge of these disks. The disks are staggered to result in give better cutting of the straw. The crop is spread on the threshing floor in circular shape and a pair of bullocks pulls machine over the dried crop. After the crop is partially broken one more charge of crop is spread and machine operation continues. The threshing is continued till the grain is separated and the straw is broken into homogeneous mixture

Fig. 4.1. Olpad thresher.

of chaff or bruised straw and grain. A pair of bullocks with operator can thresh 560 kg of grain and 1,120 kg of *bhusa* in 16 hr. The cost of threshing was about ₹ 5/100 kg of grain ($5 per tonne) during 1972-73 (Fig.4.1).

Winnowing of threshed material

When the grain is threshed by manual method or by treading with animals or using a simple drum thresher, the cleaning of material is necessary before it can be stored, bagged or marketed. Winnowing operation is essential to achieve the cleanliness of threshed grain mass. In absence of equipment farmer does the winnowing operation using natural wind by dropping the threshed mass from a height by doing so the chaff and light material is separated. A number of manually operated fans were developed to provide the sufficient amount of air blast to separate the chaff from the grain. The winnowing fan (Fig. 4.2) consists of three or four blades mounted on the shaft which is mounted on frame with a spur gear drive to increase the speed of blades. In some designs pedal operated arrangement was provided so that the opérator can sit and pedal the fan to help in cleaning operation. These devices were used in the villages at the time when there was no electric power supply available.

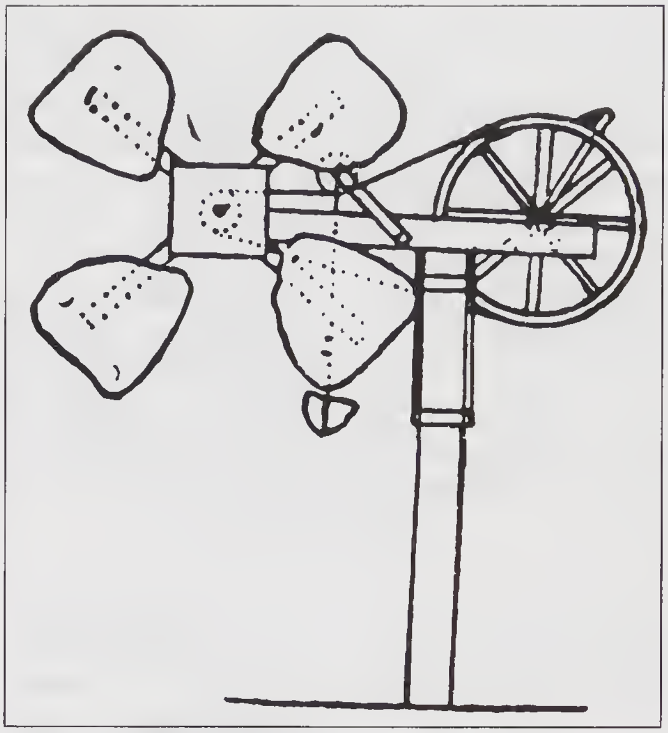

Fig. 4.2. Manually operated winnower.

A manually operated winnowing machine, which was very popular with farmers, was known as Hoshangabad winnower. Hoshangabad is a place close to Bhopal and local fabricators fabricated and supplied the machine to farmers. During 1950-1980, the machine was very much in demand in India. The winnower consisted of set of cleaning sieves and a blower just like a grain cleaner but manually operated type. The sieves did the mechanical separation based on the size and the air blast removed the chaff and light material from the grain when fed on top screen. The lower screen, which had smaller size holes, retained the grain but removed or separated the fine particles, dust and sand and weed seeds. Finally sufficiently clean grain was obtained for storage or marketing.

Power operated thresher

The machine threshed the wheat crop and made bruised straw (*bhusa*) of quality as required as an animal feed and delivered clean

grain for bagging, storage and marketing. The thresher had threshing unit where the wheat crop was beaten by hammers. The grain was separated and straw was broken into fine pieces, this mass of crop i.e. grain and straw was falling through the grate on the cleaning sieves. The aspirator blower sucked out the bruised straw and the clean grain after being separated by sieves and coming out of outlet was bagged directly. The thresher was known as Ludhiana thresher and was developed and manufactured at the factory (Fig. 4.3). Ludhiana thresher developed in Ludhiana during 1956-57 for threshing of wheat crop and making bruised straw (*bhusa*) was a highly accepted successful machine.

Description of machine: The threshing unit of machine consists of a rotor with hammers fixed at the end of arms. The rotor rotates inside a semicircular concave grate made of round bars. The top cover is made of sheet metal but sides and top surface are covered with angle irons, which act as bruising surfaces for the crop. The material is fed inside the chamber through feeding hopper. As soon as it is broken into fine pieces of 1 cm size,

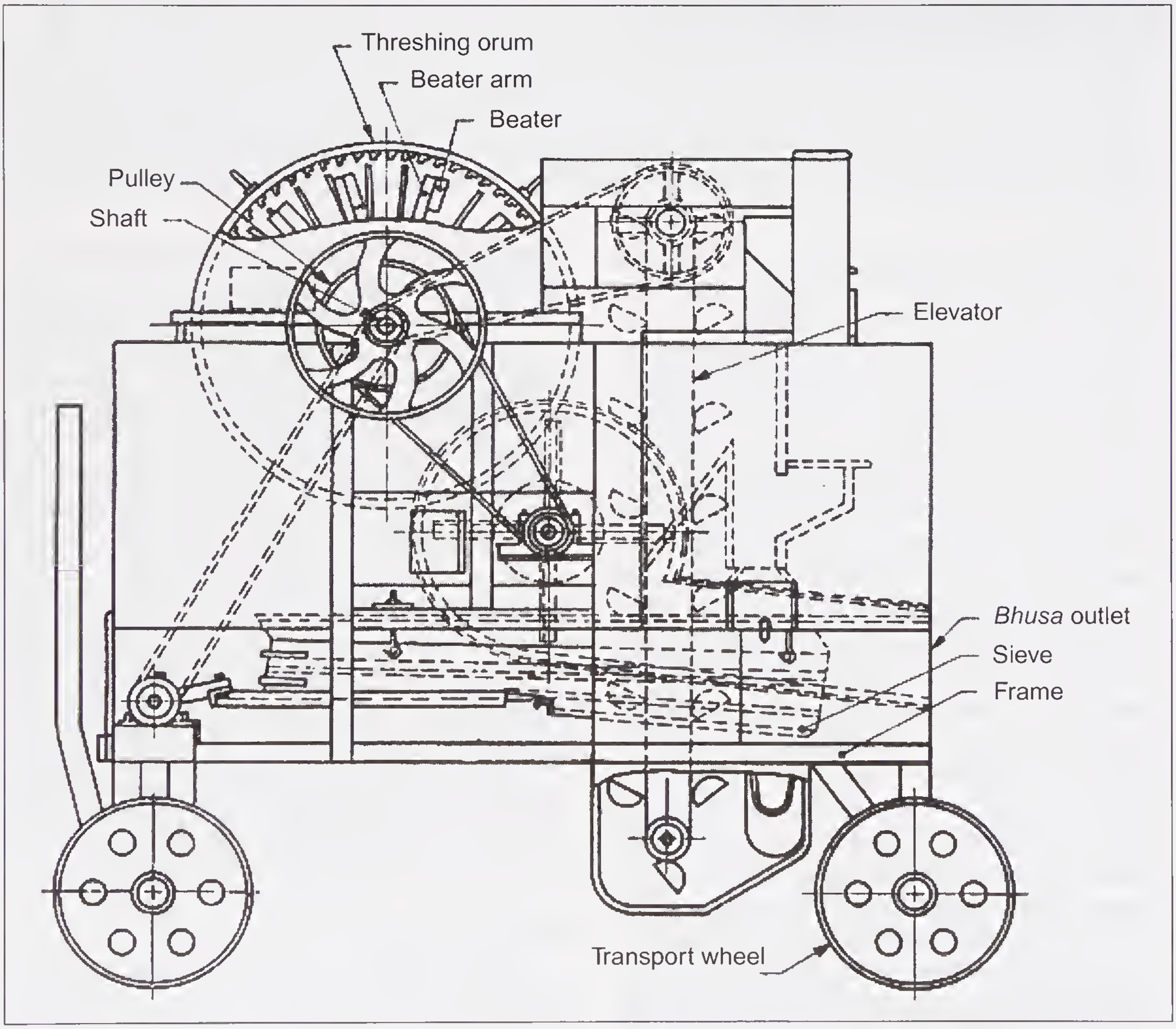

Fig. 4.3. Schematic diagram of Ludhiana thresher for wheat threshing.

it falls through the grate on the top sieve of cleaning unit.

Here with the help of aspiratory blower the bruised straw is sucked out of machine and thrown at a distance so that machine can be operated without moving it at other location. The aspiratory blower has another suction pipe located near the grain outlet from where the remaining chaff and fines are sucked and thrown out. The clean grain then falls in the bucket elevator and is lifted up and drops the grain inside the jute bag attached at the outlet. The machine was operated by a tractor PTO pulley with a flat belt. For operating the thresher farmer had to engage four workers and a tractor operator. Two workers were required to bring the crop and supply it to one who was feeding the crop into the machine and the fourth one to look after the smooth flow of material in the machine.

The farmers accepted Ludhiana thresher but the machine required a tractor for its operation and therefore another tractor for moving the material around the field was required. Thus farmers not having tractor could not mechanize the threshing. The machine had an output of 350-400 kg of clean grain/hr. It required five to six workers to operate the machine.

Drummy thresher: The need of a thresher of low horsepower to be operated by an electric motor was felt. Thus a drummy thresher was developed which was operated by an electric motor of 5 hp size. It consisted of a threshing drum with a semicircular concave and a blower. The crop fed into the drum was subjected to threshing action till it was completely broken up. The material falling from the grate was subjected to winnowing action. The straw is blown away and grain was falling on the ground. This was a low cost trouble free machine meeting the requirements of the small landowners (Fig. 4.4).

The two designs of threshers namely the Ludhiana and Drummy threshers helped in mechanizing the threshing of wheat crop in earlier times but had limitations for threshing of other crops. These threshers could handle only completely dried crops.

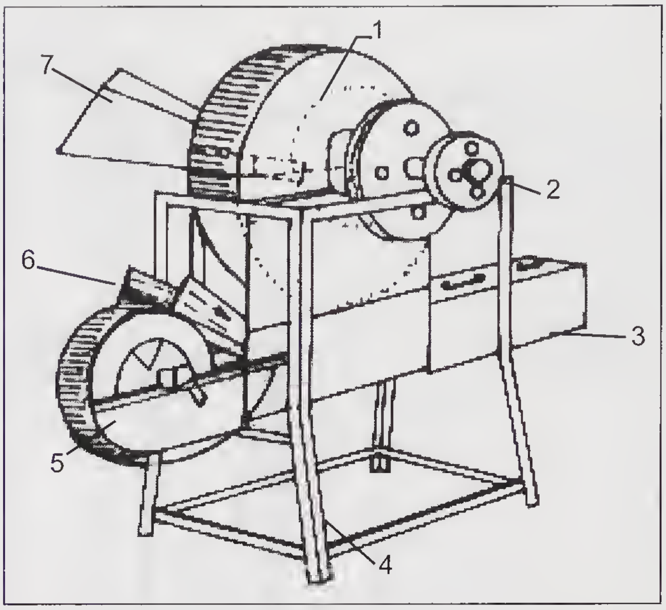

Fig. 4.4. Drummy type wheat thresher developed in India (1963-64). 1, Threshing drum; 2, Drive pulley; 3, Straw outlet; 4, Frame; 5, Blower; 6, Inlet for grain cleaning; and 7, Feed inlet.

Allahabad Institute thresher: In 1967, Allahabad Agricultural Institute, Allahabad released the design of a 5 hp size wheat thresher. It was commercialized by local industry in Punjab. This make has been the most popular design of wheat thresher used by farmers in India and other neighbouring countries. The production of these threshers exceeded the figure of 60,000 per year in India during 1980-85. A large number of small-scale thresher manufacturers located in many states of India undertook the fabrication of the machine. It was simple, rugged design and machine was easy to move around farm and was operated by an electric motor.

Description of machine: The Allahabad thresher has a threshing drum with spikes or studs as beaters (Fig. 4.5). Crop is fed axially through a feeding chute, it is threshed and straw is bruised. The entire mass of wheat crop passes through a concave grate on to the cleaning shoe, where light fractions are air

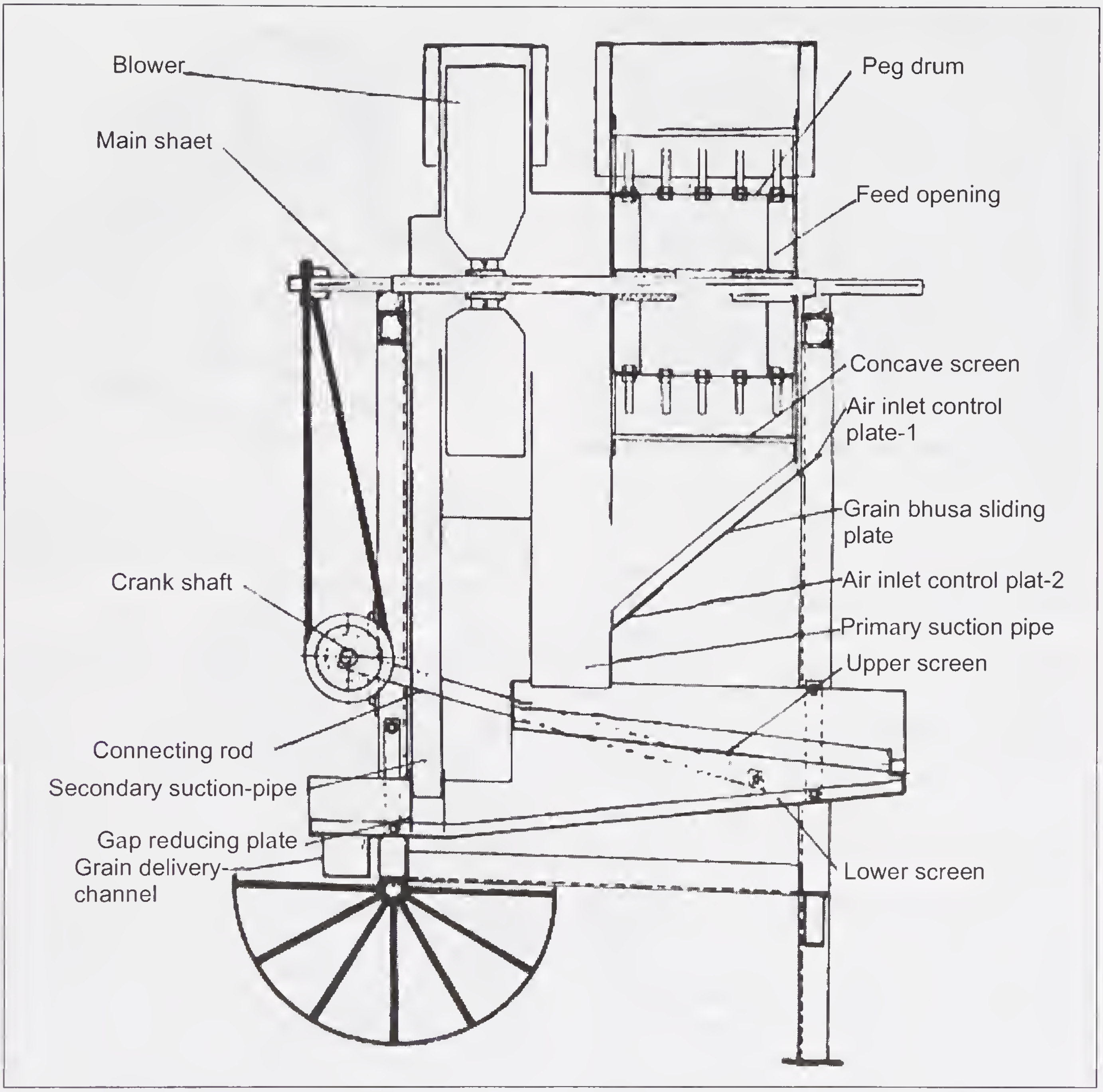

Fig. 4.5. Allahabad Agricultural Institute Thresher- spike tooth type wheat thresher.

aspirated and grain is screen separated so that the clean grain flows out of the grain outlet. In some designs the partially clean grain is subjected to air aspiration at the sieve outlet to improve the cleaning efficiency.

A typical 3.75kW thrasher has a 560 mm diameter and 330 mm wide threshing drum having 42 beaters. A flywheel of cast iron of 560 mm diameter, weighing 53 kg, is mounted on the same shaft. The aspirator blower is also mounted on the cylinder shaft has 3 blades of 130 mm width and overall diameter of 760 mm. The grain cleaner has two screens with top screen has an area of 720 × 620 mm with 4.5 or 6 mm diameter holes (1.7 holes per square cm). The bottom screen has area of

1 015 × 620 mm with 2 mm diameter holes (with 4-5 holes per square cm). The grain cleaner unit is driven from the main shaft by a cross v belt drive.

The thresher assembly is mounted on the four cast iron wheels of size 260×65 mm width. The front wheels are equipped with integral steering hitch. The feeding of crop is manual through a chute. The thresher beater shapes varies greatly and threshers with spikes use less energy than those with bolts/studs/ hammers (Fig. 4.6, 4.7).

A typical 5 hp thresher has clean grain output of 200-250 kg/h from the wheat crop having 40% of grain. The total threshing losses are within 2%. The threshing efficiency is about 99.5% and cleaning efficiency of 98%. These threshers are manufactured by a number of companies with small variations in different parts and sizes but the basic design remains the same.

Chaff cutter type thresher: The untimely rains during the threshing season created problem of threshing the wet crop. It was also noted that a few entrepreneurs had mounted

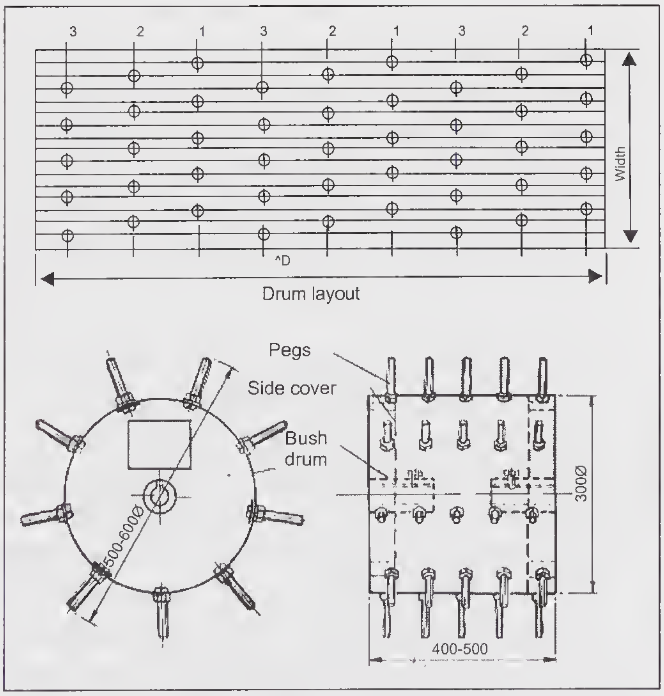

Fig. 4.6. Spike tooth threshing cylinder and its layout developed at Allahabad.

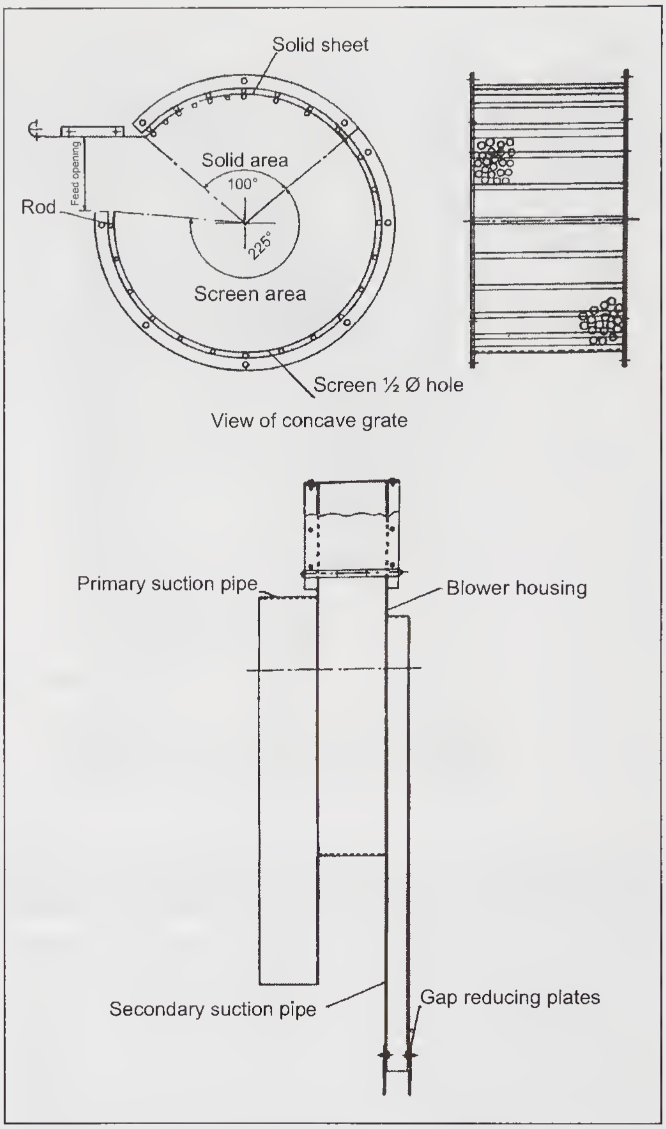

Fig. 4.7. Concave grate, upper casing of threshing cylinder and blower body.

the chaff cutters on the PTO of tractor and were doing the custom operation of chopping up the wheat crop on the farmers' fields. This machine had a very high cutting output of 2-3 tonnes/h and it left the chopped crop with the farmer. Thus farmer who had no thresher was able to salvage the grain during good/bad weather conditions by hiring of the machine. Thus a chaff cutter type thresher was developed to thresh the wet crop due to untimely rains.

The thresher developed was the adoption of chaff cutter feeding and cutting device mounted at the inlet of threshing drum. The

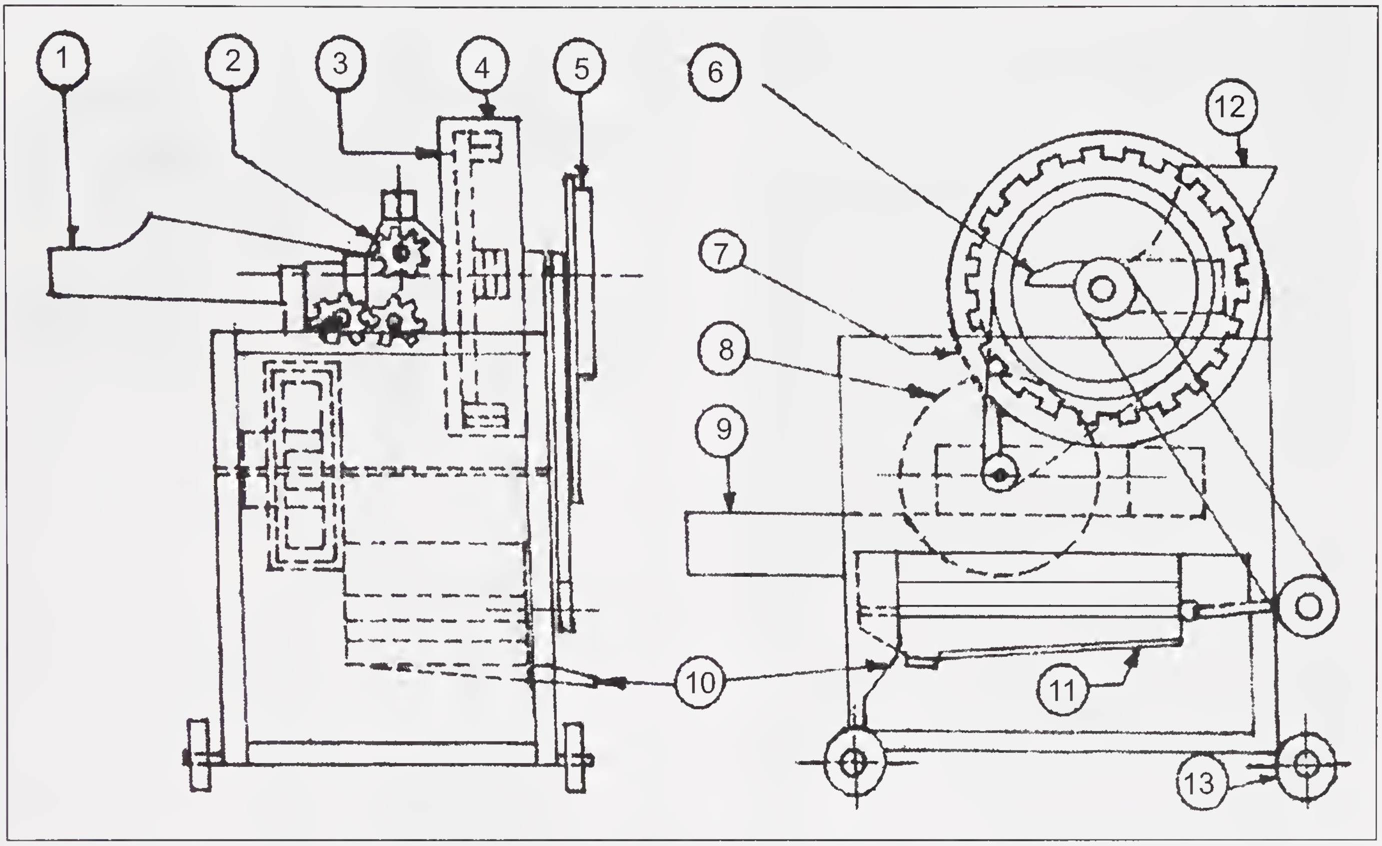

Fig. 4.8. Schematic diagram of chaff cutter type wheat thresher. 1, Feeding chute; 2, Feed rollers; 3, Knife wheel; 4, Beaters; 5, Flywheel; 6, Knife; 7, Concave; 8, Blower; 9, Straw outlet; 10, Grain outlet; 11, Oscillating sieves; 12, Tailing hopper and 13, Transport wheels.

crop is fed through the feeding rollers. The blades fastened on the radial arms of the flywheel chop the crop. The beaters further thresh the chopped material and the aspiratory blower cleans the threshed material. The use of cutting blades was able to reduce the power consumption. It also increased the output. But this design was prone to causing threshing accidents during threshing season. The latest designs are incorporated with the safety arrangements by which the operation of the feed rollers operation is reversed by a lever provided near the feeding chute (Fig 4.8). It may be of interest to note that evaluation of different designs of threshers developed at Punjab Agricultural University, Ludhiana and also manufactured in Punjab was considered essential to identify a few successful models. Table 4.1 presents the highlights of the commercial machines. Kaul and Kumar (1975) evaluated the commercial machines.

From the test results it was concluded that:

(i) The energy consumption for the threshers tested varied from 10 kWh to 50 kWh per tonne of grain output. The grain percentage was about 40% and moisture content was 8% (db). The grain loss was 0.6-4.0% with most of machine it was within 2%.

(ii) For typical thresher with output of 200- 300 kg/h the operation required 3 workers to move the crop from stack to thresher and 2 workers for operating the machine. Hence considering the optimum size of team of workers and energy consumption rates, there is no need to develop high capacity machines, because more workers would be required for continuous operation of machine.

(iii) The bruised straw would be the main

Table 4.1. A few comparative performance values of different wheat threshers obtained from the test reports 1970-74 (Kaul and Kumar, 1975).

Thresher type	Crop with grain input kg/kWh	Energy input kWh/100kg output	Broken grain loss in straw as % of output	Grain crack-age % of output	Average power input in kW	Grain output quintal/h
Ludhiana thresher (i)	46	5.14	2.4	1.4	12.1	1.9
Ludhiana thresher (ii)	81	3.69	3.4	0.3	10.1	2.6
Drummy thresher	171	1.57	N.a	0.5	4.1	2.6
Allahabad thresher (i)	113	2.3	0.1	0.2	5.6	2.4
Allahabad thresher (ii)	122	2.7	0.7	0.2	4.9	1.9
Allahabad thresher (iii)	150	2.0	1.7	2.0	4.0	2.1
Allahabad thresher (iv)	151	N.a	1.8	0.2	2.6	1.4
Drummy with Chaff cutter feeder	249	1.25	N.a	1.1	2.8	2.2
Allahabad Th. with chaff cutter feeding device	316	0.9	0.6	4.8	2.0	2.2
Bulk feeding type thresher	110	2.7	1.4	2.6	6.1	2.3
Bulk feeding Machine(ii)	122	2.37	4.0	0.3	12.9	5.4

Quintal, 100 kg; Peak power input was 50-60% above average value.

consideration in the wheat harvesting and threshing system to be adopted by the farmers.

Development of multi-crop threshers

The use and field evaluation of wheat threshers indicated the defects in the machines and development activities were directed to the designs of multipurpose, energy efficient machines, which met the needs of small farm holders. This involved the machines suitable for operation with 5 hp (3.75kW) electric motors. The various machines developed during 1970-90 are reported as follows:

PAU-multi-crop thresher: It was conventional type rasp bar threshing cylinder unit and straw walker device at the end of which was an attachment for bruising the wheat straw. This can be removed while threshing paddy crop. The cylinder diameter was 540 mm and its width was 675 mm. There were six bars on the cylinder. The concave was made from flats and round bars and covered 120 degrees of cylinder. The straw walker of 2.0 m length, in three sections was provided. Chaffer type cleaning shoe with cleaning sieves and a blower were used to clean the grain. The straw bruising attachment consisted of a spike tooth cylinder concave and a blower. The developed machine was evaluated on wheat, paddy and maize crops. The output of machine for wheat and paddy were 480 kg/h and 900 kg/h respectively when operated with tractor power. The fuel consumption was observed to be 9.6 litres/tonne of grain output. The losses were within 2.0%, cleaning efficiency was 91.5% and threshing efficiency was 97.5%. The developed machine was technically suitable but because of its size, weight and the cost it could not attract the attention of manufacturers as well as farmers.

Tractor operated multi-crop thresher: Mr Roy Harrington, developed a multicrop thresher for Indian conditions (Fig. 4.9). The design consisted of a spike tooth cylinder with fixed concave clearance of 25 mm. The cross section between cylinder and concave was 300 mm wide and 125 mm thick with 20%

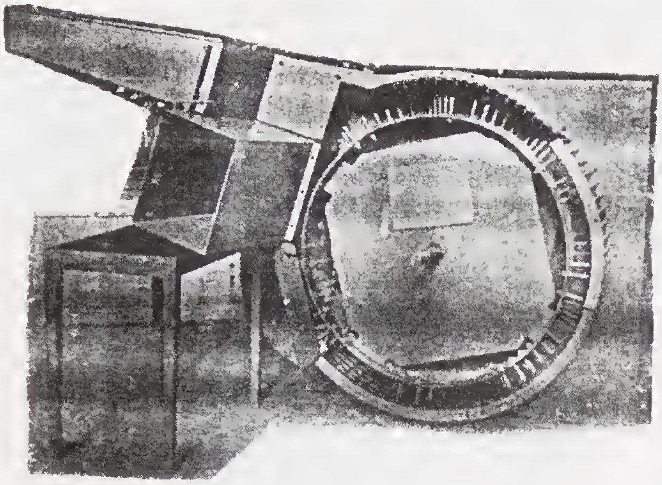

Fig. 4.9. Exposed view of tractor operated thresher developed for threshing multi-crop (*Source:* Roy Harrington).

of area occupied by the spikes on concave and cylinder. The thresher used separation grates, which are similar in appearance and in separating action to open concave. The design was chosen for simplicity and minimum space requirements. This provided agitation of material as it continuously flowed over a surface and ejected long straw or cobs but accepting grain only. The rotating cylinder was the only moving part and a few grates were provided to remove the grain from the threshed crop mass.

When the material moved out an air blast was used to separate the straw from grain. The machine was evaluated on wheat, paddy, sorghum and maize crops. The results of studies indicated that the threshing performance was good but the cleaning of grain was not satisfactory or acceptable to farmers. The thresher was developed for operation by a 20 hp tractor. The work was very useful as it helped in intensifying the development work for a multi-crop type thresher for the small farm holders. He also recommended the test procedure to be followed for evaluation of machines and developed useful information on threshing parameters for spike tooth thresher as shown in Fig 4.10.

Pusa-40 thresher: The Pusa-40 thresher was a 3.75 kW multicrop thresher designed by Agricultural Engineering Department at IARI New Delhi, to thresh wheat, barley, paddy, sorghum etc. It has a spike tooth cylinder 1,015 mm wide with overshot concave. This was placed above the cleaning device. The beater on the top of cleaning shoe delivers the threshed material.

A blower and sieves achieved the cleaning and separation. Impeller type blower lifted the clean grain into the bag. This thresher was able to thresh rice crop and also wheat crop. Even though an attachment was developed to make bruised straw but due to high cost of machine it could not compete with the commercial machines. The design was based on principles employed in the Plot thresher. The unit was able to thresh the crops but as it was unable to make *bhusa*, it could not become popular.

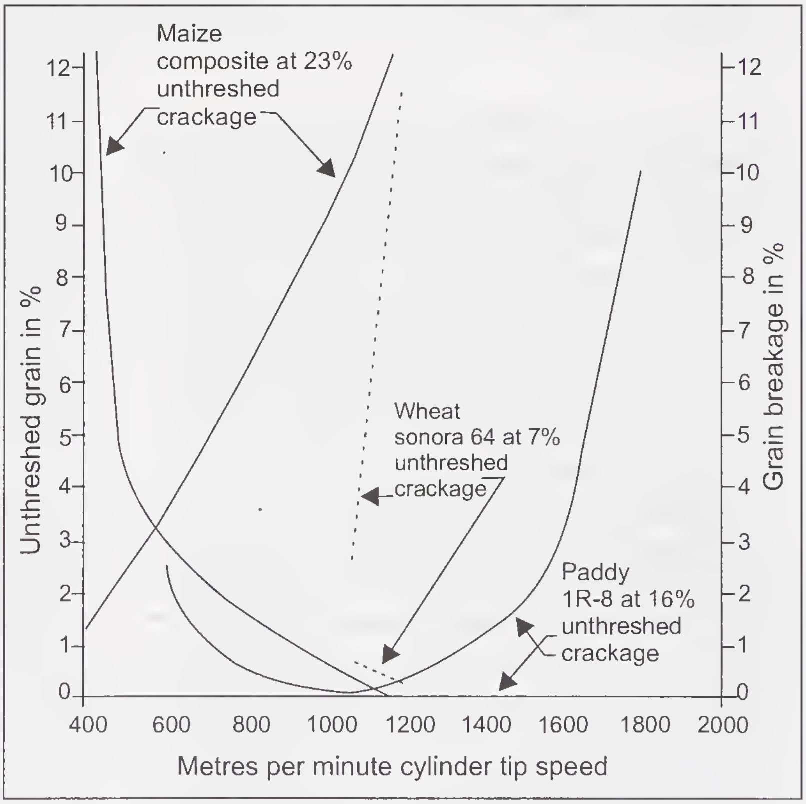

Fig. 4.10. Threshing parameters for three crops determined on the designed thresher.

IRRI-PAK thresher: In 1976, most of the areas in northern states of India was under rice-wheat as major crop rotation. The farmers were mostly raising paddy crop as irrigated and crop was harvested and threshed manually through the contractual labour. There was a great demand of a thresher which could thresh both the crops efficiently. However the threshing of paddy crop by human labour on contract basis was highly expensive. The Japanese threshers were being used in that part of the country. During the same period the success story of IRRI-Pak project was known that a successful thresher has been developed to meet the requirements of rice-wheat growing farmers. The drawings of this machine were obtained and a prototype was fabricated for testing at PAU Ludhiana during 1979-80.

Description of machine: The IRRI-PAK thresher (Fig. 4.11) has 120 cm long spike tooth cylinder consisting of threshing and breaking up of straw completely. The threshing portion of the cylinder had a diameter of 520 mm with 44 round shaped bars (bolts), whereas the bruising portion of cylinder had 495 mm diameter with 88 rectangular section spikes. The beaters were arranged helically, together with louvers in the top casing of cylinder. Crop is to be fed at one end and is ejected out at the other end of the drum after taking about 3.5 turns. The blower fitted on the cylinder shaft blows away the chaff. The grain and large pieces of straw fall on the cleaning sieve blow. The straw is scalped. An aspiratory blower does the final cleaning. To break up straw into fine pieces a gang of cutting blades is mounted in the threshing unit in case of wheat crop and

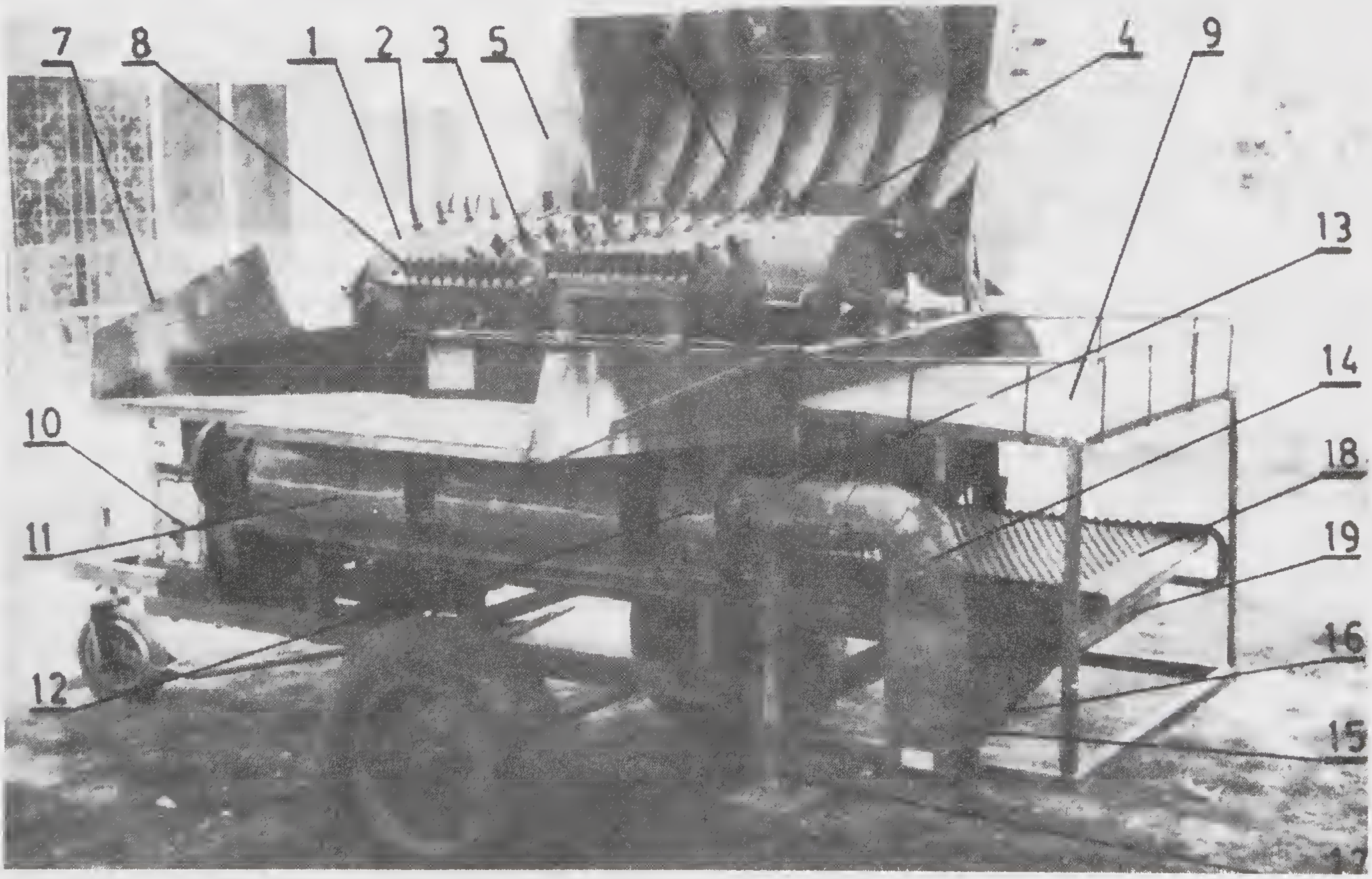

Fig. 4.11. IRRI- PAK Thresher suitable for threshing wheat and paddy crops. 1, Drum; 2, Peg type tooth; 3, Knife type teeth; 4, Paddle for straw thrower; 5, Drum cover; 6, Louvers; 7, Feeding tray, 8, Bruising bars; 9, Crop Tray; 10, Power unit; 11, Blower; 12, Suction blower; 14, Suction pipe; 15, Suction inlet; 16, Grain outlet; and 18, Top sieve.

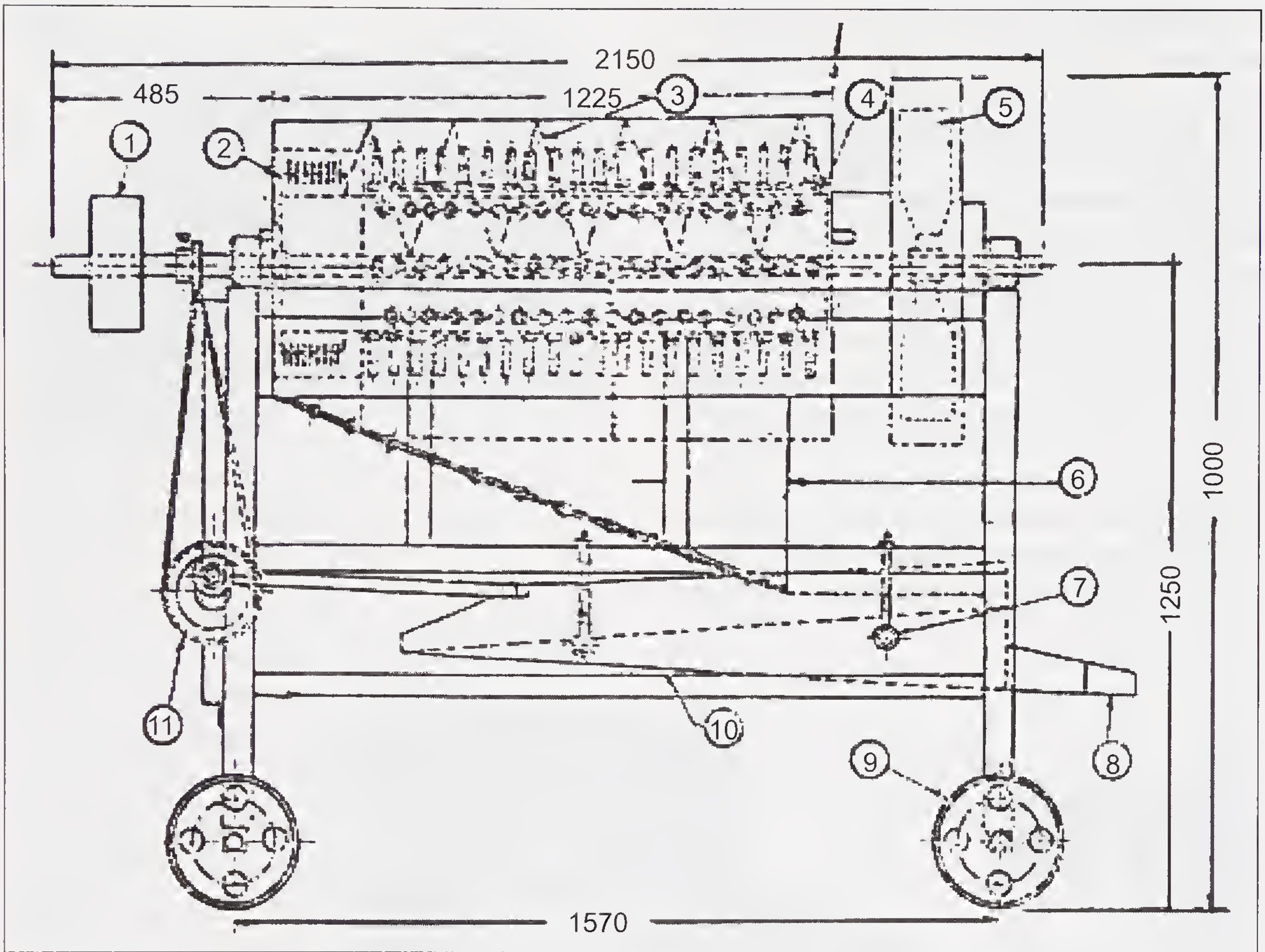

Fig 4.12. PAU wheat paddy thresher of 5 hp size. 1, Pulley; 2, Feed inlet; 3, Cylinder; 4, Feed outlet; 5, Fan; 6, Grain hopper; 7, Sieve shaker; 8, Grain outlet; 9, Transport wheel; 10, Grain receiving tray and 11, Air blower.

it is removed while threshing paddy.

The thresher when operated with 5 hp electric motor gave an output of 290 kg/h of grain. The quality of bruised straw *"bhusa"* was not acceptable to the farmers because the straw pieces with nodes were present. The grain separation was low which resulted in high sieve losses. The broken grain were 2.7-3.0% at the recommended speed. The throwing of straw from the machine was not at a sufficient distance, resulting in shifting of machine or engaging of workers to shift the bhusa. The threshing of paddy with thresher yielded an output of 500 kg/h of grain with 1.53-2.73% grain losses. The estimated cost of machine was higher than the conventional wheat thresher of comparable output. The energy requirements were from 6.7 to 16.7 kWh/tonne of grain output.

PAU wheat paddy thresher (Fig. 4.12): The thresher designed has spike tooth cylinder with 8 rows of spikes mounted on four rings of 340 mm diameter to form an open type cylinder. It was divided in three portions. The first section was 375 mm long with 15 mm diameter spikes mounted on bars at 62.5 mm spacing and the second portion has spikes mounted at 125 mm apart. The length of third portion being 150 mm long and has 4 straw throwing paddles. Thus the full length is useful for threshing paddy crop, but for wheat only the first portion of cylinder is used and the remaining portion

serves as a flywheel. The concave is made of round bars and in two distinctive portions. The first part of concave is 375 mm long, 515 mm in diameter and made of 6 mm round bars with 8 mm spacing between the bars. The second portion is 640 mm long and 454 mm in diameter with opening of 15 mm. The concave clearance in the first portion is 12.5 and 32.5 mm for wheat and paddy respectively. In the second portion it is 45 mm. The cleaning unit is as is used on conventional threshers consisting of aspiratory blower and two sieves system. The evaluation of thresher as reported appeared to have indicated good performance for threshing wheat and paddy crop with long straw. The design did not attract the attention of farmers because the labour contract rates for threshing of paddy crop were quite low to make it an attractive proposition. On the other hand the large farm holdings opted for the combine harvesters in the region. It saved time and was economical as well.

CIAE multicrop thresher: During the period 1978-79, evaluation of commercial threshers in the 5 hp (3.75kW) range was taken up to ascertain their best features and weak points for threshing crops like wheat, paddy, bengal gram, soybean, sorghum, maize and other crops. The purpose was to help farmers use one thresher to meet the mechanization of threshing crops raised in the central and other parts of India. The developed thresher incorporated the desirable features of axial flow machine and also that of Allahabad spike tooth thresher. It has spike tooth cylinder with tip diameter of 495 to 505 mm and width of 600 mm. There was 92-spike teeth mounted on 8 bars in staggered fashion. The cylinder is closed type with 180-degree concave coverage. The clearance at concave front is 25 mm and at rear it is only 10 mm. There are three types of concaves with bar openings of 7, 9, and 25 mm. Cylinder upper casing is hexagonal shape having 5 spiral louvers at 140 mm pitch to move the crop axially from feeding side to discharge end. The clearance between louvers and spikes is 40 mm. For crops other than paddy louvers are covered with a ribbed casing reducing the clearance to 25 mm and a semi circular plate is provided to meet the requirement of bruised straw making in case of wheat. The plate prevents the flow of plant material out of threshing chamber so that it is broken up in fine pieces as *bhusa*.

An aspirator and a set of reciprocating sieves separate and clean the grain. The aspirator is mounted on a separate shaft with two suction openings, one at the separating chamber and other at the grain outlet on the sieve. Cleaning sieves are hinged below the cylinder concave assembly on adjustable hangers. Three sieves of 540 × 860 mm in size are provided for cleaning the different crops. In case of crops where stems are thin and long and broken in long pieces such as bengal gram and pigeon pea the top screen portion is covered with the blank sheet to prevent clogging of sieve holes of top sieve and thus improve the cleaning action.

The thresher was evaluated on crops like wheat, soybean, sorghum, maize, paddy and gram by changing the thresher cylinder speed and using the desired size of concave the performance of thresher was satisfactory and the losses recorded were low. The power consumption was within prescribed BIS standards. The estimated cost was ₹ 8,000/- (1986-87) $500.0 approx. The cost of thresher does not include the power unit. The cost of threshing operation by the machine varied from $0.33 to $2.6 per tonne of grain for different crops (Fig. 4.13, 4.14).

The wheat threshers developed in India have been designed to use spike tooth type threshing cylinder and a concave grate. The threshing action has been achieved by allowing the material to be subjected to beating action of the spikes till the grain is threshed and falls on the top sieve of cleaning shoe along with the straw in completely bruised form. Initially the thresher cylinder and aspiratory blower were mounted on the same shaft. However, in

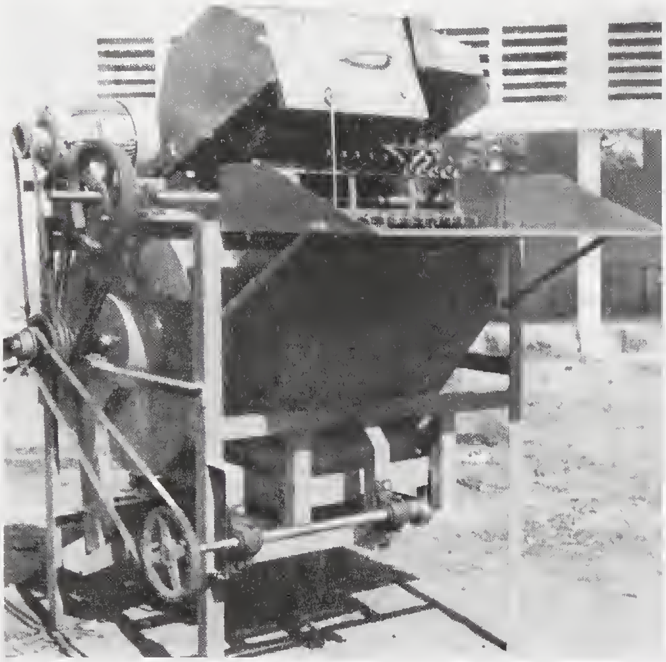

Fig. 4.13. CIAE Multicrop thresher model 1985 with axial flow threshing arrangement.

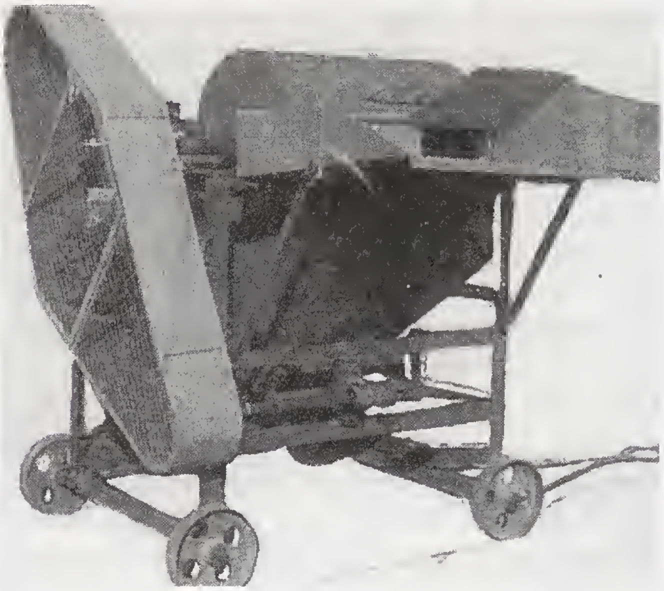

Fig. 4.14. CIAE multi-crop thresher commercial prototype.

order to make it multicrop the changes were necessary to separately mount them so that the speed of threshing cylinder can be changed without affecting the blower speed. The spike tooth cylinder (Fig. 4.15) was found suitable for threshing crops like gram, soybean, lentil, sorghum and maize cobs etc. The use of aspiratory blower and proper cleaning sieves mounted on the CIAE multicrop thresher were able to give cleaning efficiency of 96-98%. The output of thresher with 5 hp (3.75kW) motor was 150-300 kg/h. The thresher can be modified to use it as axial flow thresher in case of paddy crop harvested at a high moisture level. The machine is suitable for small farmers practicing rice-wheat, rice-legume, and soybean-wheat crop rotations. It is a low cost simple in design and can be fabricated in many of the developing countries of Asia and Africa.

High capacity thresher

The need for bigger size threshers was felt by the farmers due to increase in production and productivity levels in the country. In

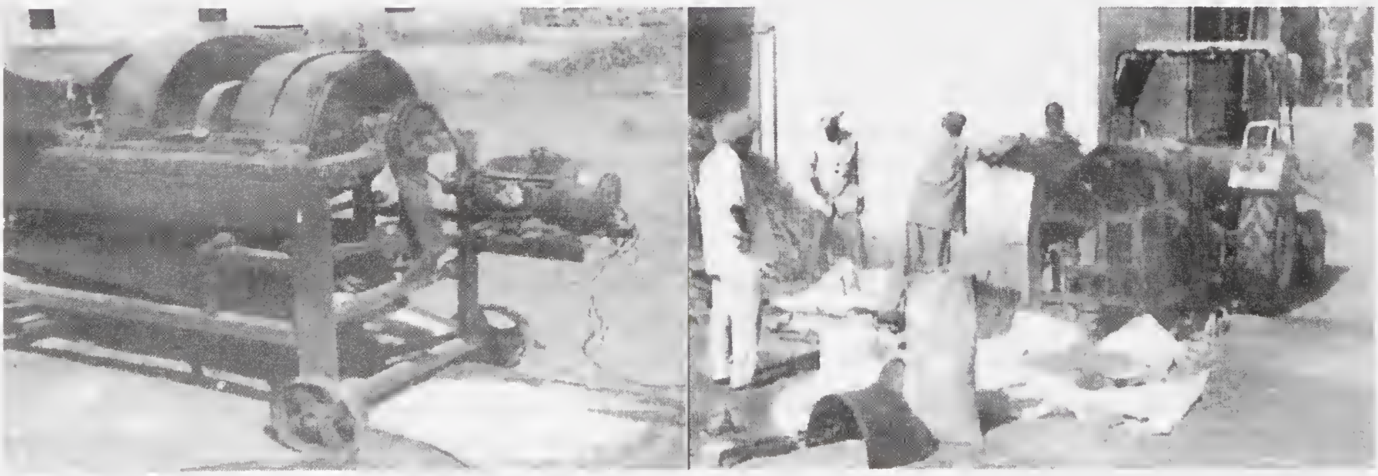

Fig. 4.15. Commercial spike tooth threshers of multicrop type manufactured in India (*left*) electric motor and (*right*) tractor operated machines.

developed states the average output of grains per hectare had crossed the level of 10.0 tonnes/ha/year. The yield levels in rice crop have also shown remarkable increases. Thus high capacity machines were developed. The initial machine of high capacity used was the tractor mounted chaff cutter. It chopped up the wheat crop in 1.2 to 1.5 cm. pieces, which was then further bruised by either moving animals or tractor over the crop. By winnowing grain was separated. This method caused grain damage up to 4-5%, but was quick to do the job in short time. It was practiced in the state of Rajasthan during 1976-85.

Fig. 4.17. Commercial unit of tractor operated high capacity multi-crop thresher with chaff cutter type feeding system.

CIAE semi axial flow thresher: The CIAE, Bhopal reported the development of semi axial flow thresher of 7.5 hp size for threshing of rice and soybean and other crops. The output capacity varied from 350-1350 kg/h with grain loss of 0.5 to 1.5% and threshing efficiency of 99.5% and cleaning efficiency of 99%.

CIAE high capacity thresher (Fig. 4.16 and 4.17): It is the scaled up model of CIAE - multicrop thresher. Dumping the crop bunches in the big feeding hopper does the feeding to threshing unit. To provide proper removal of straw or *bhusa* mass after threshing of crop three suction type blowers were provided. It is provided with cleaning shoe of three-sieve type, to achieve high level of cleaning efficiency. It is powered by 15 hp electric motor or operated by the tractor p.t.o drive. The output of grain varied from 533 kg to 2,890 kg/h with grain losses within 0.5 to 3.6 % at the cylinder speed varying from 8.0 to 14.6 m/s for different crops.

Fig. 4.16. CIAE high capacity thresher for multi-crop threshing.

The threshers of different capacities have been developed for threshing of wheat crop during the last 50 years to meet the requirements of all categories of farmers. They are based on spike tooth type threshing drum, as the farmers require the straw of wheat in bruised condition to use it as animal feed. The use

of combine harvesters is also increasing on the farms in developed areas. However the machines have been developed to recover the straw left in the fields. The farmers do not practice the burning of straw after the harvest of wheat. The price of wheat straw can be equated to the value equal to 40% of grain cost. It is also considered equivalent to the cost of fertilizer used in production of wheat crop.

The production of wheat in India has reached to 80 million tonnes, and thus 80-90 million tonnes of bruised straw is produced as animal feed. Most of the wheat crop produced is threshed with threshers. It is because of two reasons i) the cost of thresher is affordable ii) The hot climatic conditions are unfit for the farm worker to work in ambient conditions where temperatures can rise to 40-44° C. Therefore use of thresher can complete the job of threshing in a period of 2 to 3 days by working late hours. The only problems now to be tackled are the level of noise, vibrations and atmospheric pollution due to operation of machines. The comfort and safety of operators need greater attention of the designers.

❑

5 Cross Flow Threshers

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The three types of configurations of threshing cylinders widely used for threshing of crops on combine harvesters and power threshers in developed countries from 1930 are known as rasp bar, spike tooth and rub bar type cylinders. Rasp bar cylinders are widely used on combine harvesters for threshing most of the crops. Spike tooth cylinders are used on threshing of rice crop and windrowed beans. The rub bar type cylinders are used mostly for threshing of millets or crops having pods. The spike tooth cylinder has concave with spike tooth fitted in rows and cylinder teeth pass midway between the teeth on the concave. This produces the combing action in addition to impact for threshing of rice crop. The main object of rub bar cylinder and concave design is to obtain threshing of grain or seed separation action without damaging the seed of the crops such as beans and pods where seed are tender and are likely to get damaged. In rub bar cylinders the concaves are also lined and are fitted with rubber bars. The primary function of the concave bars is to hold the material and subject it for the repeated impacts during the threshing operation. The high-speed motion pictures indicated that in wheat threshing the separation of grain occurs due to impact or shattering action of cylinder bars hitting the heads. Further there was rubbing action due to movement of material through the slit which also contributed to threshing action.

The conventional rasp bar threshing

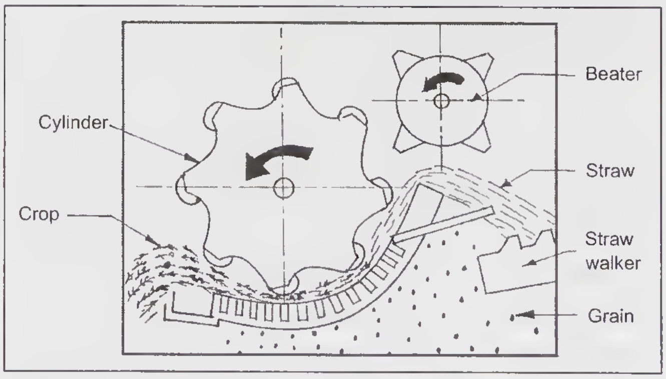

Fig. 5.1. Sectional view of threshing unit of combine harvester.

unit showing the material flow through the machine is shown in Fig. 5.1.

The performance of threshing units is expressed in terms of % of seed detached from the non-grain (straw) part of the plants and the % of seed damage during the operation. The other two parameters of importance are (i) the separation of grain through the concave grate and (ii) degree of breaking of straw. These two factors influence the performance of cleaning and separating units. The break-up of straw increase the power consumption and also affects the cleaning efficiency of cleaning shoe. When the threshing unit breaks up crop straw extensively, the output of threshing unit is reduced considerably. The separation of seed at the concave grate is important as it reduces the load on the straw walker. Hence the threshing action should be achieved with high threshing efficiency with maximum of grain separation at the concave grate and minimum of straw breakage and seed damage.

The impact blows received during the threshing process cause most of the seed or grain damage. Thus the crops, which are easy to thresh, should not be retained at the concave for long time during the threshing process. The seed damage also occurs while conveying the material from the concave to straw walker. The seed damage is of two types; the visible damage in the form of broken grain and invisible one i.e. internal damage. The other invisible damage is when the grain is reduced to powdery state and is removed with the straw or air. This damage occurs when crop is very dry (less than 10 % moisture content).

The thresh ability of crop is affected greatly by the threshing unit design factors, operating conditions (speed of cylinder, concave clearance, time interval crop is retained in the cylinder, number of rows of spikes and covering of grate only in some crops) and the crop characteristics (moisture content, maturity level and type of crop).

The major design factors are cylinder diameter and bar spacing, length of concave and size of concave openings. The studies on design factors were conducted at NIAE, Silsoe, UK for cross flow-threshing units on wheat and barley at grain moisture levels ranging from 14 to 26%. The cylinder diameters were in the range of 381 mm to 686 mm and 610 mm wide. The concave used was open grate type. The material was fed into cylinder by means of variable speed conveyor belt. The performance was analyzed by determining the percentage of unthreshed, broken seed, germination, seed separation through concave grate and broken straw.

Cylinder diameter and bar spacing

In NIAE tests, Arnold and Lake (1964) concluded that cylinder diameter was not of the major importance and hence diameter be chosen to suit the desired concave length. Diameter from 533 mm and above had less effect on separation of grain when concave length was 330 mm. However, changing of peripheral spacing of rasp bars on cylinder had also little effect upon performance.

The diameters of rasp bar cylinder and spike tooth cross flow cylinders are generally 480 to 600 mm with 559 mm most prevalent,

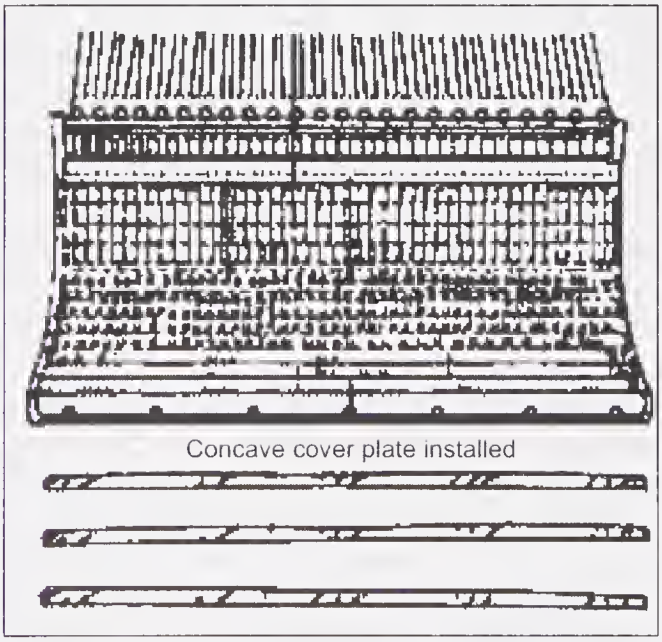

Fig. 5.2. Blanking bars used on concave for hard to thresh crops.

and the width of cylinders range from 685 to 1,525 mm on the combine harvesters with cutter bars up to 7 m length. Most of rasp bar cylinders are fitted with open grate concaves with rectangular bars parallel to cylinder axis (Fig 5.2, 5.4). The clearance between bars is adjustable to suit the different size of seeds to be threshed.

Length of concave: From these tests Arnold and Lake further reported that increasing the length of concave increased the seed separation efficiency but at a diminishing rate. With wheat the first 169 mm section of concave removed 52 to 55% of grain and each successive 169 mm section up to a total length of 678 mm removed about 40% of the grain on that section. Increasing the length increased the straw break up and also tended to increase the seed damage especially at low moisture content and high cylinder speeds. Under easy threshing conditions, there was little advantage as regards to cylinder loss of using concave longer than 330 mm but increasing length up to 508 mm reduced the loss under difficult conditions. Thus concave length was limited to 508 mm beyond which there was no appreciable improvement in seed separation.

Concave opening: In these studies operating the concave covered in 356 mm long concave while threshing wheat at 15% and 24% moisture and cylinder speed ranging from 18 to 33 mps and mean concave and cylinder clearance of 6 to 13 mm, the seed damage was substantially greater with concave opening covered compared to open conditions, but there was no appreciable effect on cylinder loss or straw break up reported. Therefore, covering the concave can result in high straw walker losses due to greater seed damage.

Neal and cooper (1972) studied comparative performance for the cross flow rasp bar cylinder and open grate concave with a spike tooth cylinder with regard to seed separation through the grate in rice crop under laboratory conditions. The tests indicated that at a non-grain feed rate of 90 kg/min. approximately 72% of the grain was separated by rasp bar unit but only 50% by spike tooth grate. A spike tooth cylinder inherently has considerably less open area than the grate used for rasp bar cylinders. They also confirmed that increasing the length of concave beyond 508 mm did not help in separation of grain at the concave.

Effect of operating conditions on threshing units (Fig 5.3)

The important operating conditions for threshing units are the peripheral speed and the concave cylinder clearance. The clearance affects the time interval for the material retained at the cylinder concave contact zone. In case of spike tooth the numbers of rows of concave teeth influence the movement. The next operating condition is the covering of concave grate.

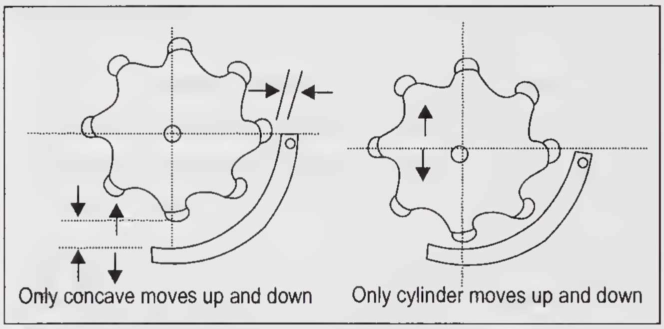

Fig. 5.3. Two methods used for setting concave clearances for cross flow-threshing unit.

The other operating conditions related to the crop are type of crop, moisture content, its maturity level and the feed rate of the material. However the performance of threshing unit is generally determined in terms of loss and seed damage.

Cylinder speed: The cylinder speed is the most important operating parameter in regard to cylinder loss and grain damage. Generally increasing the speed reduces the cylinder loss but increases the grain damage. The susceptibility of seed to damage varies greatly among the different crops and the same crop at different moisture level. In general when the moisture level of crop is low the seed

damage increases from the optimum level. Many investigators have reported that the germination of wheat reduced when threshed at grain moisture content above or below 17 to 22%. Similar trend was reported for rice when the milling operation of the threshed paddy is considered in terms of head rice recovery or as regards to corn kernel damage. In brief, it was reported that in case of wheat the loss was minimum at cylinder speed of 23 mps for low moisture level and 26 mps for 20% moisture level. The values of speed for different crops have been determined and reported in Table 5.1.

Concave cylinder clearance: The seed losses are dependent upon the concave cylinder clearances. Reducing the concave clearances tend to reduce the cylinder or threshing losses but increase the seed damage. Arnold and Lake (1964) compared the performance of front to rear clearance ratios of 3 to 1 and 1 to 1 and observed very little difference in cylinder loss, visible damage and germination of barley and wheat for any given mean clearance. Front to rear clearance convergence is generally desirable because wider front opening tend to improve the feeding characteristic of a cylinder. Increasing the non-grain feed rate in case of combine, it means cutting the crop close to ground increases cylinder losses. The relationship is often close to linear. Increasing the feed rates tend to reduce seed damage although the effect is usually small. The high feed rate increases the material density passing between cylinder and concave, therefore, it provides more cushioning material for the grain and thereby reducing the damage.

The grain damage occurs because of small concave clearance, and also due to impact blows received during threshing process. Time interval to pass the grain through the concave grate is also responsible for the damage. It also depends on the crop conditions as well as feed rate and susceptibility of different kinds of seeds due to impact damage. The laboratory tests conducted on the seeds have confirmed that damage is caused primarily due to impact of threshing drum and, therefore, cylinder be operated at low speeds to avoid damage. Thus in some designs two threshing cylinders are used in series, the first cylinder is operated at low speed to remove most of the seeds and the second one at higher speed to remove the left over seeds from crop without causing excessive damage especially in case of beans.

The moisture content of crop and grain also influence the grain damage. In case the crop is dry the speed of cylinder is reduced. There is optimum level of grain moisture at which the grain damage is minimal. It increases as the moisture content is increased or reduced from this range.

The seed loss is dependent upon the feed rate to the threshing unit. However, the loss due to unthreshed ears may be very small because in most of the machines the tailings are circulated for rethreshing. Thus the loss of unthreshed material in combines is influenced by the effectiveness of separating and cleaning units.

Cylinder adjustments: The crop conditions during harvesting season vary from day to day and also during the same day. Therefore cylinder speeds are changed and clearances are adjusted to suit the different crop conditions. The cylinder speed is changed either by means of variable speed v-belt drive controllable by the operator or by changing sprocket on a roller chain drive. The clearances are adjusted by lever mechanisms by moving the cylinder or the concave or by adjusting the length of tooth. The arrangement is such that both the front and rear clearances are changed simultaneously but with less change at the rear than at the front. The best cylinder speed is selected after considering the various parameters of the crop, and clearances are selected for the particular crop situation. Based upon experiments conducted on threshing of crops typical range of peripheral speed and clearances are given in Table 5.1. The cylinder speeds are always given in peripheral speeds

Table 5.1. Typical cylinder peripheral speeds and clearances used for threshing of selected crops on cross flow threshing units on combine harvesters (*Source:* Balmer, Kapner and Barger 1955).

Crop	Peripheral speed for rasp bar and spike tooth (meters per minute)	Mean clearance for rasp bar cylinder (millimetres)
Barley	23-28	6-13
Beans	8-15	8-19
Beans for seed	5-8	8-19
Corn	13-20	22-29
Grain sorghum	20-25	6-13
Oats	25-30	5-13
Peas	10-15	8-19
Rice	23-28	5-10
Soybean	15-20	10-19
Wheat	25-30	5-13

rather than rotational speeds. The speeds used are low in case of multi-pass cylinders. In dry climates, the speeds are set at low level to avoid seed and straw breakage. The other adjustments on the cylinder may be to reduce the number of rasp bars for easy to thresh crops. In spike tooth cylinder, the numbers of spikes are reduced to reduce the impact action on seeds or grain.

Effect of operating conditions on the performance: In case of combine harvesters with rasp bar cylinders and open grate concaves the seed separation of 60-90 % is achieved at the concave grate. Increasing the speed of cylinder or decreasing the clearances forces more grain to pass through the grate therefore reduces the amount of seed to be handled by straw walkers. Thus the operating conditions influence two things, the straw break up and grain separation by the threshing unit. When the crop is dry at low moisture level the seed separation increased in barley, but in wheat there was no effect in the moisture range of 14 to 24% as reported by Arnold in the laboratory tests. It was concluded that percentage in wheat tended to be higher than with barley. Thus operating conditions are to be adjusted according to crop being handled.

The second important factor is the effect of grain to non-grain feed rate effect. In case of wheat crop the grain in the crop is around

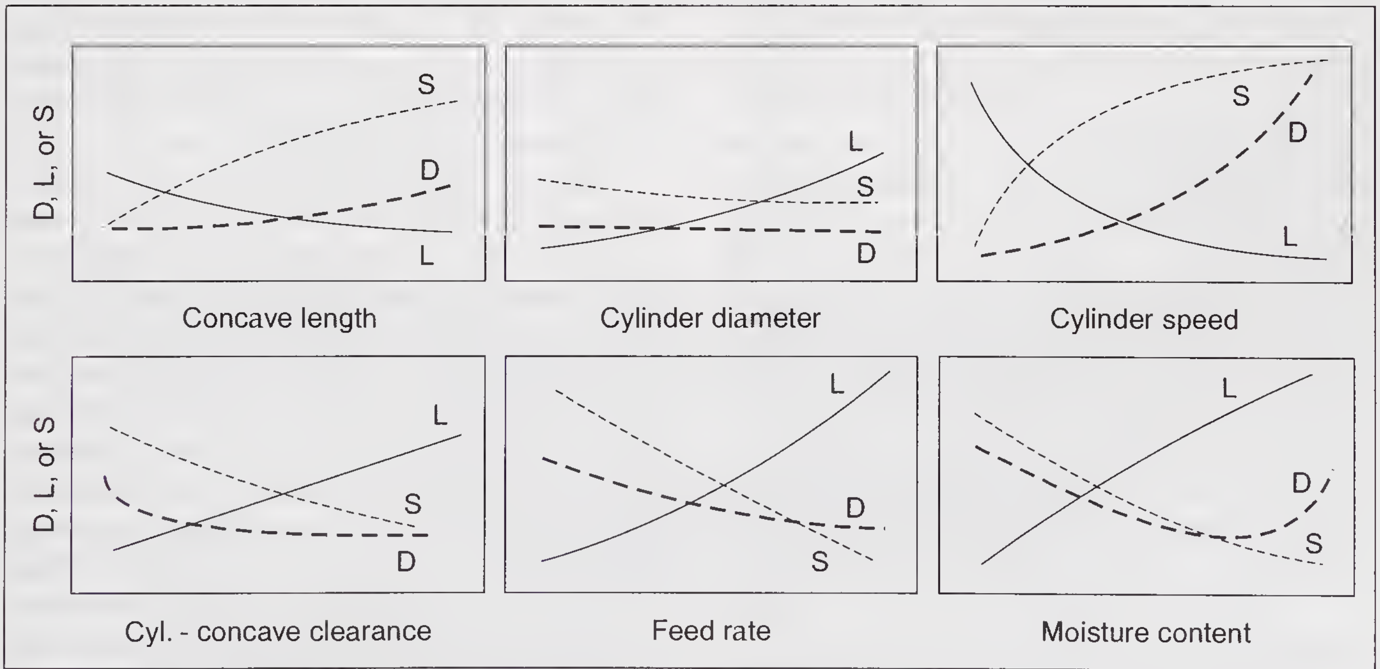

Fig. 5.4. Wienke's graphical characterizations of performance relations for a rasp bar cylinder with an open grate concave (L = Cylinder loss, D = Grain damage and S = Per cent of grain separation through concave grate)

40%. Thus grain to non grain feed ratio is 1: 1.5; Analysis of data by Reed *et al.* (1973) and his associates in laboratory tests with wheat from 9 to 10 per cent moisture content indicated that increasing grain to non-grain ratio from 0.7 to 1.0 had no effect on separation efficiency at a given non grain feed rate.

The separation decreased from 80% at a non-grain feed rate of 90 kg/min to 70% at 180 kg/min when the cylinder width was 813 mm. In barley no effect was reported due to grain/ non-grain ratio. The straw break is influenced by kind of crop and its maturity. In general straw break up increases, as material is dry and increase if cylinder speed is increased. Concave clearance has less effect on straw break up. Increasing grain to non-grain ratio from 0.7 to 1.0 in laboratory tests with wheat increased the flow of non-grain material through the concave thereby reducing the non-grain feed rate on the straw walker by 7 to 9 %. For the cross flow thresher lot of studies have been done in many countries to link up the effect of design factors and operating conditions with performance characteristics. Thus six factors discussed are concave length, cylinder diameter, cylinder concave clearance, cylinder speed, feed rate and crop moisture content. These show the effect on cylinder loss (L), grain damage (D) and per cent of grain separation (S) at the concave grate. The studies were conducted in UK and Germany independently. Wienke developed the graphical representation of the performance of rasp bar cylinder with open concave grate. The effect of six factors is represented in terms of cylinder loss, grain damage and % separation graphically in Fig.5.4. Thus variation of six parameters can be studied as they are either increased or decreased for most of the conditions.

Separation of grain from straw

There are two stages of grain separation from straw. The first one refers to the grain being separated at the concave itself, the remaining quantity is separated at the straw walker. A straw walker separating unit has three to six side by side sections each being 203 to 305 mm wide. The area of straw walker varies from 6 to 16 times the concave grate area in combine harvesters. The sections are attached to a multiple throw crankshaft near the front and another at the rear. The straw walkers, due to motion, accelerate the material in the forward upward direction during the portion of each cycle. This action of walker motion with the aid of saw tooth fins conveys the straw towards the rear of the machine. As the straw is agitated, grain from straw is separated and it passes through the openings in the walker and is conveyed on to the grain pan or to the front of cleaning shoe. The troughs like sections are provided below the individual walker sections with proper slope to allow the grain to slide into the cleaning unit. Most of the straw walkers have crank throw of 102 mm and crank speed of 185 to 225 rpm. The crank speed is determined from the relation that the centrifugal force acting on the mass is twice the force of gravity, which will make the net upward force at the top of travel equal to "g". The speed calculations by this relationship are 188 rpm and 102 mm stroke length or 152 mm throw of crank and 153 rpm. These are close to speeds used on combine harvesters.

Rotary separation device: The use of rotary separation devices instead of straw walkers was also adopted on machines. In this system there is a stationary grate and one or more vanes rotors, which operate at high speed. The crop material rubs against the separating grates as it is rotated and moves outward through the straw opening. The grain is moved out of the grate openings due to centrifugal force. The magnitude of centrifugal force acting on material is very high (200g) when the peripheral speed of rotor is 20 mps.

The other design had a rotating perforated cylinder into which the material is fed from the conventional threshing unit. The perforated rotating drum axis was horizontal, the

diameter of drum was 0.68 m and its length was 2.74 m. The perforation size was 13 mm diameter and rotational speed of 348 rpm. A parallel auger about 229 mm in diameter was located close to the inner surface of drum near the top strips the grain from straw grain mixture from the drum surface. With the assistance of blower the material moves to the discharge end. After the stripped material has passed the auger the centrifugal force again throws the material towards the drum periphery. The magnitude of centrifugal force is approximately one time the force of gravity. The grain straw mixture passed through the perforation is conveyed to the front of machine by means of augers to the conventional cleaning shoe for further separation and cleaning. Regarding performance of the drum system it was reported that even with high feed rates, its separation losses are considerably less than walker loss from a comparable size of conventional machines.

Kinematics of straw walker (Fig. 5.5)

The motion of threshed material on the straw walker is governed by resilience of straw, resistance to airflow and interaction between the straw layers close to the section of the walker. The operating conditions of straw layer on walker are considered optimal when the straw swells to maximum extent during its fall and compact to minimum extent during the agitation of the rack. These conditions are obtained at the crank speed of 190 to 220 rpm with crank radius of 0.05 m. When the speed is low the straw is tossed up only and the actuator passes below it. The height of fall of mass becomes low and straw-tossing action is small. The speed at which the straw grain mass moves over the straw walker significantly affects the separation of the grain from the straw. As the forward speed of straw mass increases this reduces the thickness of straw layer on the rack thus reduces the time interval for which the straw stays on the walker.

Straw walker index: The operation of straw walker at optimal conditions results in low grain loss. The speed of walker serves as the index of its operation. Straw walker index is represented as the ratio of angular acceleration of the actuators and the gravitational acceleration.

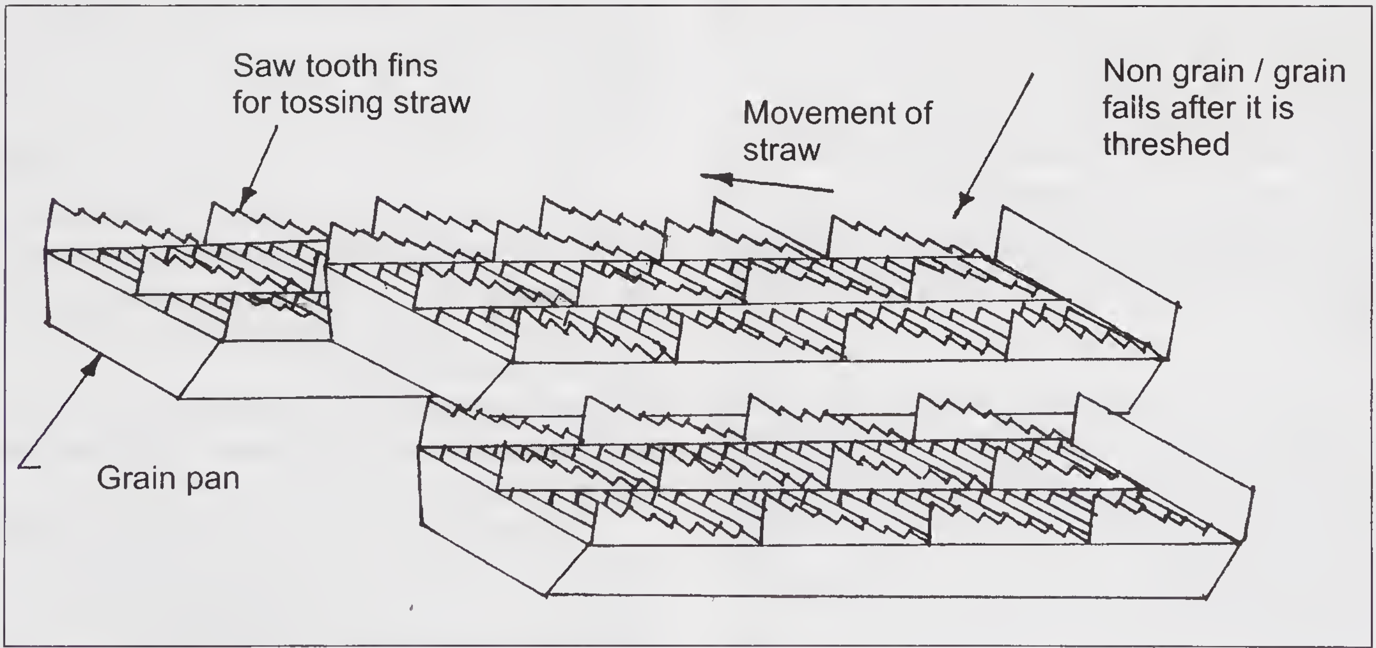

Fig. 5.5. View of a straw walker used for separation of grain from straw.

i.e., $$K = \frac{\omega^2 \times r}{g} \tag{5.1}$$

Where, r, crank radius in m; ω, angular velocity of shaft in radians/sec, and g, acceleration due to gravity.

During the operation of machine, the loading rate (q_{av}) for walker varied from 0.67 q_{av} to 1.33 q_{av} due to non-uniform harvest conditions. Load fluctuations cause the variations in speed of walker to deviate from the specified values. In case the value of K is low the losses will increase (Fig.5.6). The losses increase when the value of K is above 2.6. Thus straw walker should be operated at constant speed and close to optimum value.

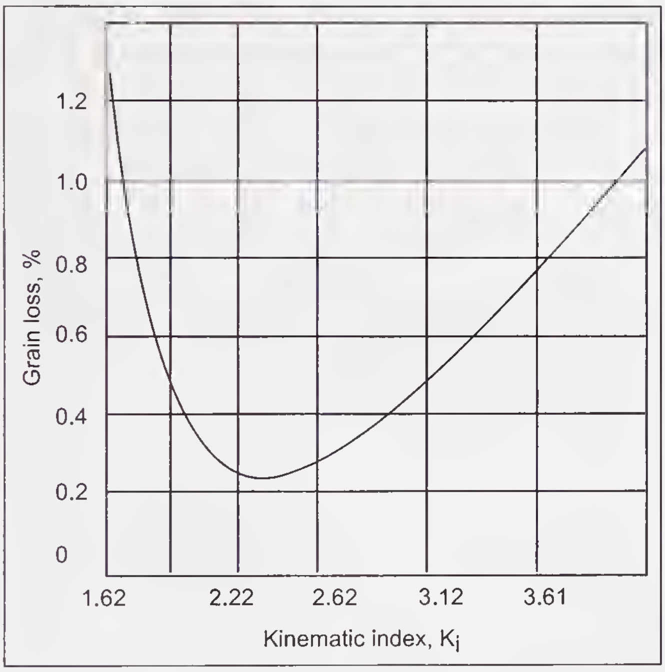

Fig. 5.6. Effect of straw walker index on the grain loss of a combine harvester (*Source:* Klenin *et al.*, 1985).

Separation of grain from straw: The sifting of grain on the straw walker is governed by α (the probability of grain passing through the straw acting as the sieve) and β (the probability of grain passing through the walker screen). The probability of total grain mass sifted per unit length of straw walker is given by

$$\mu = (\alpha \times \beta / V_{av} \times t) \tag{5.2}$$

Where, V_{av}, average speed of movement of straw mass along the straw walker length m/s; t, time interval between successive tossing in second; and μ, coefficient of separation.

The intensity of separation is the ratio of quantity of grain sifted per unit length at any portion of walker to the total mass fed to it. Thus the quantity of total grain y decreases with the distance traversed by the straw mass on the walker (Fig. 5.7).

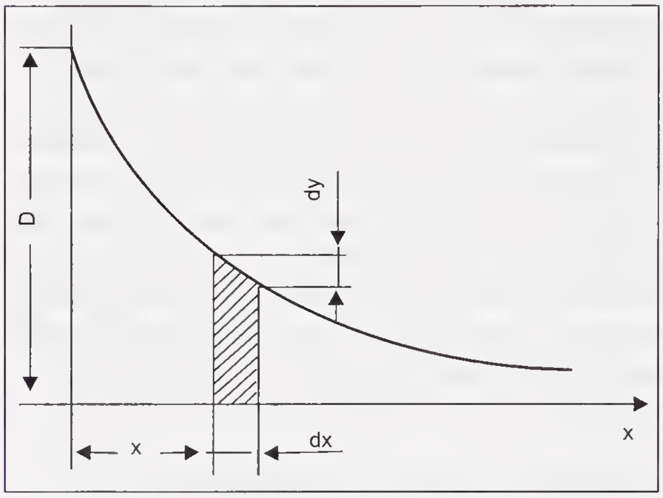

Fig. 5.7. Decrease of grain amount in straw mass along the length of the straw walker.

dy/dx = μ . y where, y , inflow of grain in the elemental length dx of the walker; x, distance of element dx from the inlet of the walker;

$$\text{or, } y_L = a \cdot e^{-\mu \cdot L} \tag{5.3}$$

Where, y_L, amount of grain leaving straw walker at length L in kg/sec; a, feed rate on the straw walker kg/s. L, length of straw walker in m; e, base of natural logarithms; and μ, coefficient of separation.

This relationship indicates that for the low level of losses, the length of straw walker should be large.

The value of μ depends on the thickness of the straw layer. Let it be considered as H. The values of H and μ are represented by an equation of rectangular hyperbola, i.e.

$$\mu / \mu_1 = [H_1 / H]\, m \tag{5.4}$$

The value of m = 0.8 to 1.2, the value of m is low for light loading of walker and the value m is high for heavy loading of weather.

For H = 20 cm and grain to straw ratio of 1: 1.5, the value of μ reported was 0.018 sec^{-1}.

Relation of feed rate on straw walker *(Fig. 5.8):* The handling capacity of the straw walker is restricted by the permissible grain loss as it is reported that the losses in combine harvesters are mostly due to straw walkers. The permissible loss of grain in straw is 0.4 to 0.5% of the total grain.

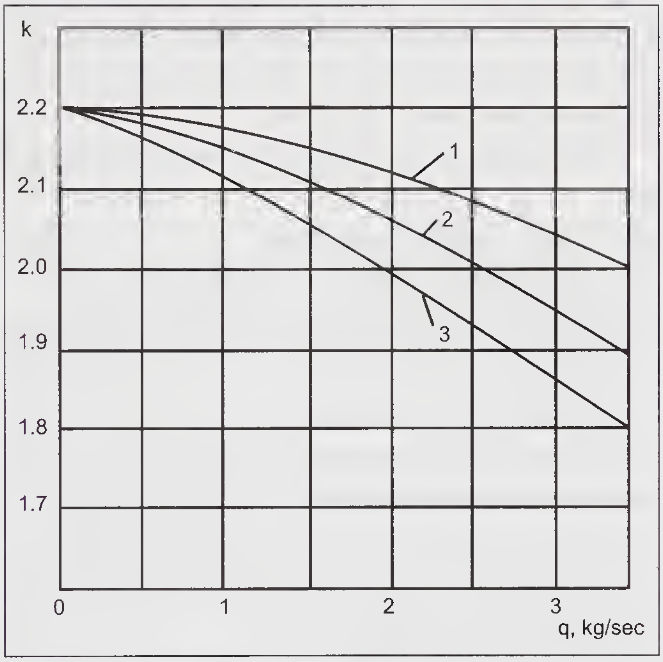

Fig. 5.8. Variation of the kinematics index of the straw walker as a function of the feed rate (*Source:* Klenin *et al.*, 1985).

The loss of grain from straw walker Ls

$$Ls\ \% = (y\ /\delta.q) \times 100$$
$$= (a\ .\ e^{-\mu L} / \delta \times q) \times 100 \qquad (5.5)$$

δ, grain to non-grain ratio of material fed on the walker; and q, feed rate of crop, kg/sec;

The quantity of grain sifted at the concave by coefficient "ε"

$$\alpha = (1-\varepsilon)\ .\delta\ .q$$
$$Ls\ \% = 100\ (1-\varepsilon)\ e^{-\mu.L} \qquad (5.6)$$

Thus the loss of grain or straw walker depends on μ, which depends on feed rate q and quantity of grain sifted at the concave.

Determination of thickness of layer on straw walker: Let volume of straw fed on walker per second is V_1

$$V_1 = q\ (1-\delta)\ /\ \gamma 1 \qquad (5.7)$$

where, γ1, density of straw layer on walker (approximate 12 to 17 kg/m³)

If the residence time of grain and straw mass moving at speed v_{as} over the walker of length L is t. Therefore,

$$t = L\ /\ v_{as}$$

Let the volume of straw, which moves along with the walker, is equal to V

$$V = V_1 \times t = V_1 \times L\ /\ v_{as} \qquad (5.8)$$

Where V, volume of straw; and v_{as}, the speed of the straw layer.

Let H, height of straw layer; and B, width of the walker; and L, length of walker in m

$$H \times B \times L = V_1 \times L\ /\ v_{as}$$
$$H \times B = V_1 /\ v_{as} \qquad (5.9)$$

Putting the value of V_1 from equation given above

$$H \times B = q\ (1-\delta)\ /\ \gamma 1 \times v_{as}$$
$$\text{or } H = q\ (1-\delta)\ /\gamma 1\ \times v_{as} \times B \qquad (5.10)$$

Thus the thickness of straw layer on straw walker depends on the feed rate and the grain to non-grain ratio and indirectly on the mass density of straw, width of walker and the velocity of straw moving on the walker. Thus the loss of grain from the walker can be calculated if the value of feed rate, the coefficient of separation and thickness of straw layer is known using the above equations. It is reported that effect of increase in width of straw walker has greater effect on the reduction of losses compared to increase in length because there are greater chances of grain to pass through a thin layer of straw as compared to thick layer. The normal length

used is in the range from 2.4 to 4.0 m for most of the combines.

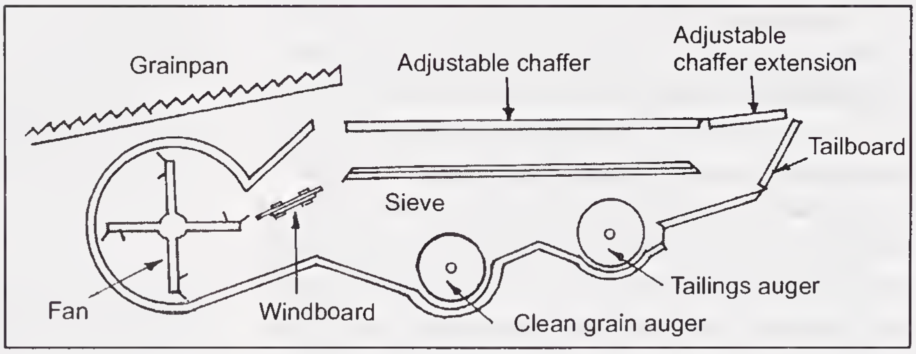

Fig. 5.9. Schematic of the cleaning shoe with adjustable chaffer.

Straw walker performance

The major portion of losses in the combine harvesters is attributed to the losses due to walker. This loss is affected by the two factors namely non-grain feed rate and grain to non-grain ratio for the given crop. The comprehensive tests were conducted at the University of Saskatchewan to determine the effect of walker crank speed, crank throw, grain to non-grain ratio, feed rate and other factors on the efficiency of separation. The test set up included a complete straw walker assembly of 203 mm wide and 2.44 m long section and it was fed by rasp bar cylinder in the same manner as in conventional combine. The crop was harvested by reaper binder and conditioned to achieve moisture level of 9 to 10%. The walker losses for different feed rates at three crank speeds and two crank throws were determined. The lowest losses were at 200 rpm with 102 mm crank throw and 150 rpm with 152 mm crank throw. The total feed rates ranged from 45 to 135.0 kg/min. with walkers operated at both throws of crank. The losses were same in both cases, however, when 152 mm crank throw was used; a check curtain was needed to have acceptable performance. The tests were performed with different feed rates and different ratio of grain to non-grain material. This was achieved by adding the chopped straw and chaff. The losses for walker increased rapidly as the non-grain feed rate reached 90 kg/min. Therefore, increasing the amount of grain had no effect upon the amount of grain not separated by walker.

Cleaning shoe performance

The cleaning shoe (Fig. 5.9) used on combine harvester is a two screen type unit. The material from straw walker and threshing cylinder is dropped on the grain pan and is allowed to fall on the chaffer sieve, where it is subjected to cleaning action.

The shoe performance in brief is affected by

- Crop condition and type
- Non-grain feed rate on shoe
- Grain to non-grain ratio of material on the shoe
- Slope of the machine
- Shoe adjustments and its design.

Performance parameters

The performance parameters are the

- Grain loss
- Cleaning efficiency and
- Amount of tailings recovered

The grain loss is the major parameter for the performance and cleaning is some times sacrificed to reduce the grain loss. The amount of tailings should be minimum because the recirculation of tailings causes greater amount of load on the shoe thereby the losses. The shoe loss may be the major loss of the total operation loss in a combine harvester. The shoe loss increases as the non-grain feed rate or when the shoe is overloaded. Therefore uniform distribution of material on the chaffer sieve is important to avoid the losses or over loading of a particular section of shoe. Thus any change in operating conditions or crop, which reduces the intake of non-grain material

and improves the threshing at concave without causing excessive breakage of straw helps in reducing the shoe losses.

Adjustments on shoe

The three adjustments provided on shoe are:

i) Control the size of opening on the chaffer sieve
ii) Control the opening size of sieve and replace it with sieve of desired hole size
iii) Control the volume of air from the blower or fan and its direction.

Other adjustments provided vary upon the size of opening on the chaffer extension and slope of chaffer sieve. The trend is to reduce the number of adjustments on the machines. However the volume of air directed on shoe sieve needs careful adjustment and control to obtain clean grain.

The cross flow threshers used in advanced countries are considered as technical advanced machines. The threshing unit has high capacity for threshing and consumes less amount of energy on the basis of unit amount of grain threshed. The fabrication of parts of cross flow type machines involves better manufacturing facilities. Such facilities were not available with small-scale industry producing farm equipment in developing countries during 1970-1980. Therefore, simple thresher designs were developed to meet the requirements of farmers and keeping in view the production technology of local industry. No sooner such machines were imported by research organization in developing countries, the modified and simplified models were fabricated, tested and commercialized. However, in Punjab state where mechanization was encouraged local industry started production of combine harvesters to meet the demand of the big land holders. During 1985-90, a number of combine harvester companies were started and these were using the same designs as used in USA and Europe during 1960. Thus the local industry upgraded itself to produce combine harvesters at the competitive cost. A few big industries also started collaborative ventures with foreign firms to manufacture combine harvesters in India during this period. The trend is continuing to use local and imported machines as required by the farmers. The present quality and quantity of these machines is highly encouraging. This was greatly encouraged by using combines for custom hiring to the farmers of other states. However the problems and limitations of such machines are reported to help users of combines in reducing the operational losses. It is expected that users of old machines would be benefited by the theoretical and applied information covered in this chapter.

❑

6 Theory of Threshing

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The theories developed and utilized for threshing of crops are presented in this chapter. It is started with the theory developed for the cross flow or tangential type threshing units used on threshers and combine harvesters developed in the developed countries during 1930-40. At this time most of the threshing units were fitted with rasp bar type cylinders. The threshing of grain from the ears enclosed in the husks can be achieved by striking the ears or by rubbing and squeezing action. In striking and rubbing action the material is to be deposited on the hard surface. The crop is fed into cylinder through the feed inlet; the threshing drum is attached with the rasp bars on its circumference, which is revolving at speed. The concave represents the sieve of transverse rectangular steel bars set at parallel to drum axis. These bars enable the threshing and separation of the threshed grain from the straw at the concave. The concave surface encloses the drum over a certain length of its circumference. The width of slit at the inlet is generally more than at the outlet end. It depends upon the type of crop material, its moisture content and the extent of threshing action required. The rasp bars are specially shaped and the direction and inclination of

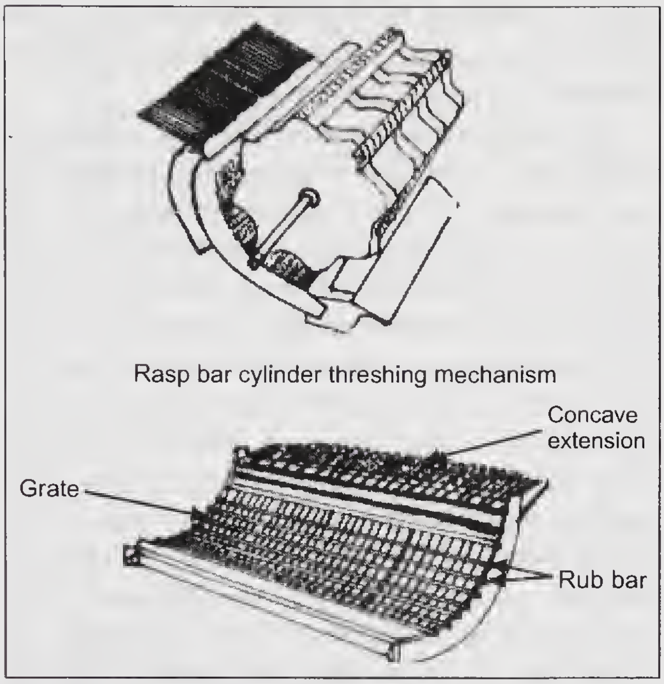

Fig. 6.1. Rasp bar type threshing drum and concave unit.

ribs on the individual bars are opposed to each other to avoid pulling of material in one direction. Fig.6.1 gives the view of concave and threshing drum fitted with rasp bars.

Threshing with rasp bar cylinder (Fig 6.2): The rasp bars strike the material fed into the drum; it is pulled inside the working slit and shifted through the slit with varying speed. Thus there occurs the slip between the surfaces of rasp bar and the shifted material, the value of which at the inlet opening is the highest on account of low pressure and with increasing convergence of the working slit the value of slip reaches its lowest value at the outlet. The concave bars on the other hand restrain the speed of travelling stalks clamped on the rasp bars close to concave surface. It follows from that the rasp bars move in the working slit with a varying speed with respect to concave. As a result of which the crop layer is struck several times by the bars causing predominant amount of threshing of grain and causes acceleration of straw. This causes rubbing of the stalks as well as rubbing of ears against the edges of stationary bars of concave and the

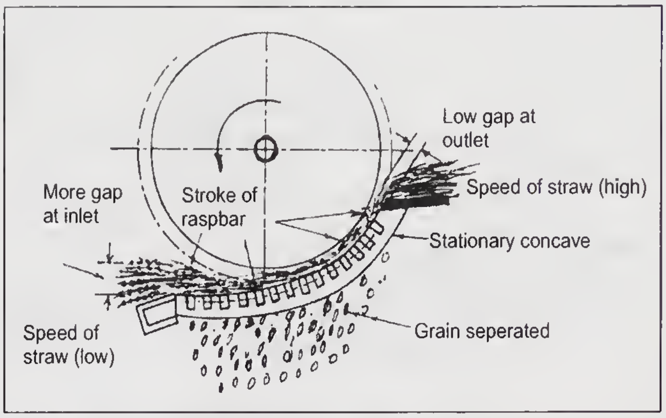

Fig. 6.2. Action of rasps bars on the crop while passing through the concave surface.

breaking of stalks depending upon their initial setting at the feed inlet.

The strokes of successive rasp bars against grain layer represent the elastic material as assumed but it may be viscoplastic-elastic depending upon the crop characteristics. Thus it expands between the successive rasp bar strokes. As the result of which there occurs in the layer forced radial vibrations equal to the number of strokes of rasp bars during the time particular section of layer to be shifted through the working slit. As the grain shifts towards the progressively converging slit it is compressed more and amplitude of vibration decreases, whereas the speed of layer increases. In addition to forced vibration there also occur in the threshed layer self excited vibrations caused by the friction of the threshed layer against the concave. The engineers at Poland have explained this as theory of threshing. Thus from this it is concluded that the effectiveness of threshing is better, when less of unthreshed grain and threshed loose grain is ejected with the straw from the outlet slit of concave, the less of grain is damaged and greater amount of straw is passed through the outlet of concave on to the straw walker. Thus one should harvest the crop when it is at proper moisture content for the efficient operation of the thresher. When the crop is dry the threshing action on the straw is more resulting in more breakage of

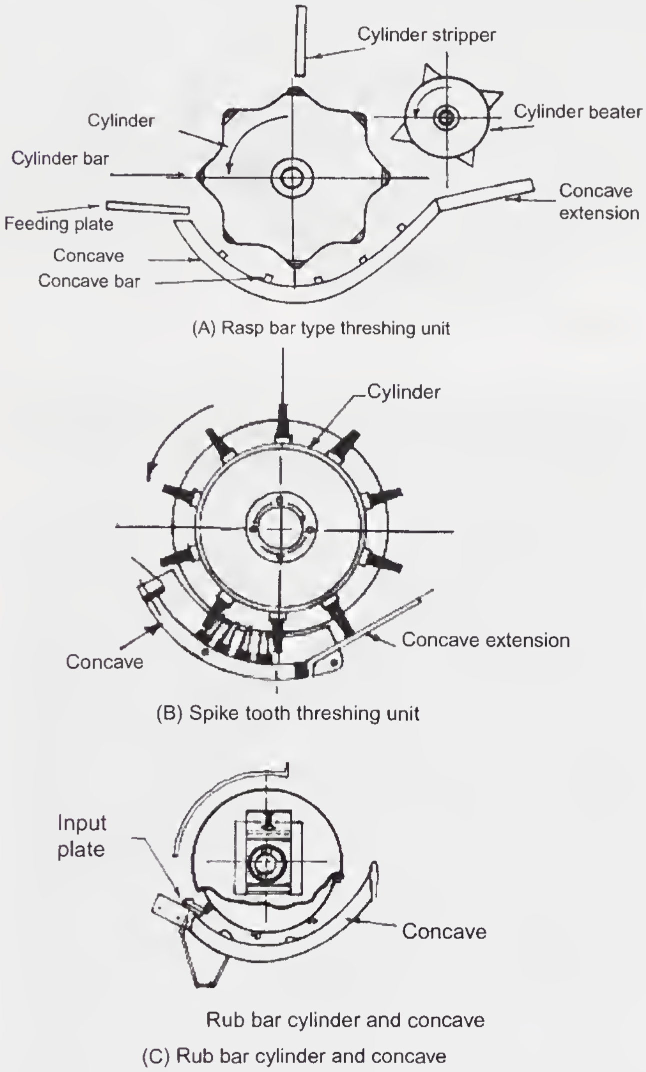

Fig. 6.3. Three designs (A-C) of cross-flow threshing cylinders.

straw and thus it would cause increased load on the cleaning shoe. Thus more trash in the clean grain is received. When the threshing cylinder speed is increased, the frequency and amplitude of self-excited vibrations of the threshed layer are increased and thereby the unthreshed grain amount is reduced. The threshing efficiency of 98-99% is desirable. In hard to thresh crops better threshing effect is achieved by increasing the peripheral speed of cylinder. Increasing the length of concave surface at the unchanged peripheral speed of rasp bars causes similar phenomenon. Thus unthreshed grain losses can be reduced by either increasing the speed with use of short concave or by increasing the length of concave surface.

In damp crop because of high values of coefficient of friction between the individual components of straw mass, penetration of grain through the shifted layer is slow which causes low output and poor threshing. The force required to detach the grain is also high, thus threshing is achieved by increasing speed of cylinder. There are two types of threshing cylinders of rasp bar type. These are called an open type and shielded drum type. The pulling capacity of open drum is more than the shielded drum. The presence of cavities between successive rasp bars facilitates grain threshing due to increase in the amplitude of vibrations. By increasing the number of bars from six to eight diminishes the gripping capacity of the drum, which causes the reduction of speed of the shifted layer. The grain damage is more when the speed is high, low concave clearance, high concave length of the threshing unit.

Effect of cylinder type on threshing performance

The diameter of the threshing drum affects the quantitative capacity of the sifting of grain through the concave. With an increase in feeding rate there occurs a lower acceleration of grain layer in the working slit with large drum diameter than the smaller one. With an increase in feed rate the separating capacity is better with large diameter cylinder and the output of threshing unit increases provided the wrapping angle of concave is greater than 90 degrees. In feeding material downward through the feeding hopper the initial pull of drum is higher. The best effect is achieved when grain layer is fed in tangential direction to cylinder.

The spike tooth cylinder used for threshing consists of a drum on the circumference of which are attached the teeth distributed along helical lines and concave is also equipped with

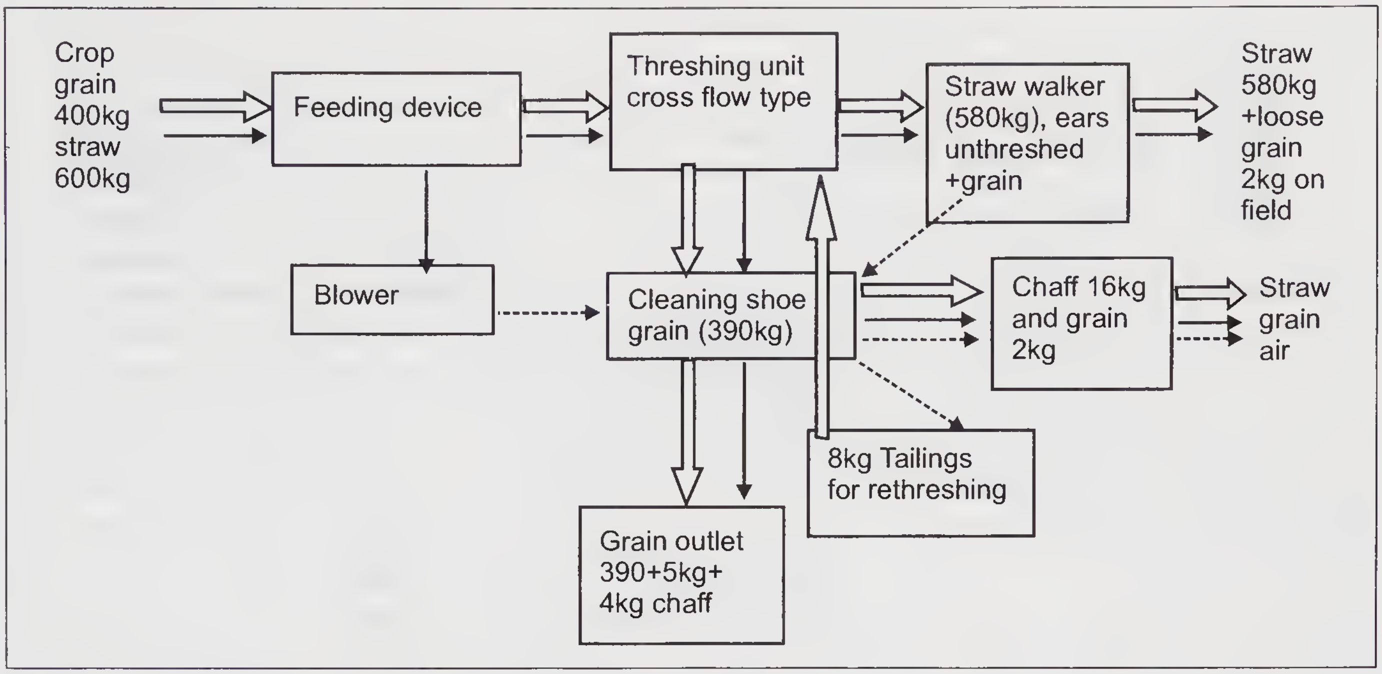

Fig. 6.4. Flow diagram of crop for cross-flow threshing units.

several rows of appropriated arranged teeth. The pulling capacity and output of tooth type drum of identical dimensions is higher than that of rasp bar unit. It is reported that the separation capacity of grain at the concave is less. In rub bar threshing cylinder there is predominately-squeezing action on the crop due to rubber-lined bars and the concave surface. This type of threshing cylinder is used for threshing of beans and pods of tender seeds. All the three types of threshing units as shown in Fig. 6.3 are used on commercially available combine harvesters manufactured in advanced countries during 1930 to 1975.

The flow diagram of cross flow thresher drawn for the optimum crop conditions is given in Fig. 6.4. The diagram shows the grain content in crop is 40%. It will be noted that the straw breakup at threshing unit is shown as 15-18%. Threshing efficiency is shown as 97.5 % with threshing loss of 0.5%. It would be noted that the load on straw walker increases as the volume and weight of non-grain material increases. With the increase in yield levels during and after the green revolution the amount of crop material to be handled increased and thus it resulted in inefficient operation of combine harvesters. These designs were in use up to 1975.

Radial flow wheat threshers

The wheat threshers developed in India are different from the cross flow threshers because in India the farmers had interest in straw, as it is an important component of animal feed. They preferred to use the traditional method of threshing over the thresher in which straw was not processed into fine pieces; locally called as bhusa or bruised straw. The crop-harvesting season in wheat crop is dry and the crop moisture can go below 10%. At this stage straw is brittle. Thus the thresher developed used the principle of hammer mill. The entire crop fed into the threshing cylinder is beaten with hammers mounted on rotating shaft inside the chamber, which is fitted with grate made of square or round bars with 12 mm spacing. It covers the chamber for 180 degrees. The sides and upper part of chamber are also fitted with bars or angles to provide the rubbing surface to break up the straw into 1.0 cm size pulverized mass and separate the grain.

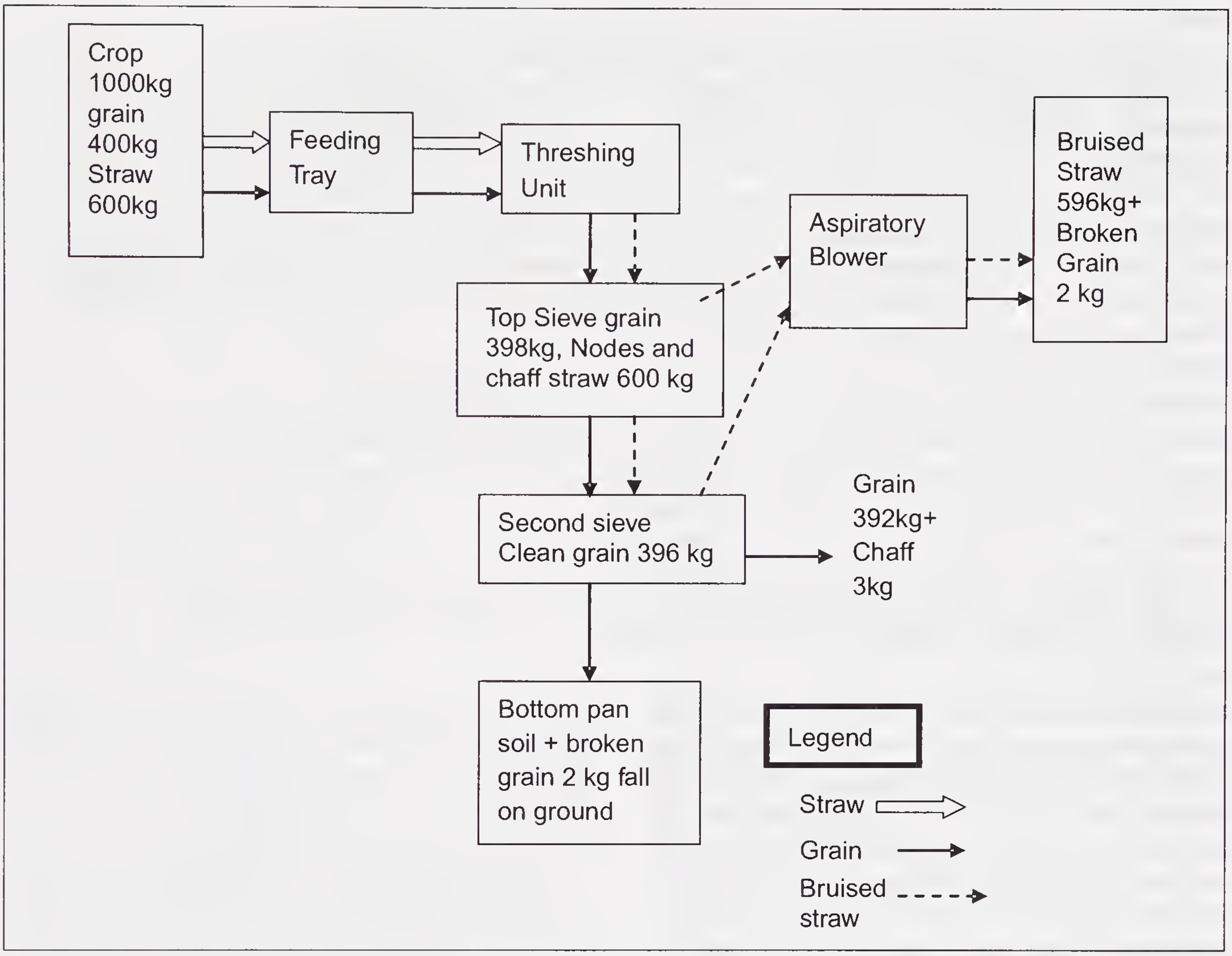

Fig. 6.5. Crop flow diagram of a radial flow or hammer mill type wheat thresher.

The hammers while striking the crop material pull in the material inside the chamber and thus delivering the kinetic energy in breaking up the crop mass into fine pieces till it passes through the concave sieve. The entire mass of crop falls on the top screen of cleaning unit. Thus crop material inside the chamber is broken up till it falls through the grate. Above the cleaning sieve is the inlet of aspiratory blower, which sucks out the entire broken straw mass and throws out of the machine at a distance. The top screen allows the grain to pass through it and the second screen helps in removing the small seeds and broken grains. The clean grain is collected at grain outlet and is lifted up by bucket elevator to the bagging unit. The thresher was operated by the tractor PTO and run at speed of 550-600 rpm. The thresher was able to thresh about 400 kg of clean grain and with 600 kg of bruised straw. The material flow diagram of Indian wheat thresher is given in Fig. 6.5. The aspiratory blower is able to suck out the bruised straw from the threshed material completely, which is acceptable by the farmers as clean grain. (Cleaning efficiency achieved was above 99 %). Thus it consumed energy in breaking up the straw and also it consumed more energy by suction action by the blower to remove the *bhusa* from the threshed material. The total losses during its operation were less than 2%. The energy consumption was high around 20

kWh per tonne.

The second design of thresher was for the machine to be operated by an electric motor as during this period there were a small number of tractors with the farmers. The design consisted of a chamber fitted with grate into which hammers on rotating shaft were mounted. In this machine instead of aspiratory blower a simple blower was fitted below the chamber for winnowing the bruised straw and allowing clean grain to fall on the ground. This thresher was simple in design and of low cost. It did the threshing job well (separation of grain from ears) but left the grain and trash. Thus to have clean grain it required further cleaning. Once the crop was threshed, it was easy to clean by using the blower for the winnowing action.

The third design of wheat thresher was developed at Allahabad Agricultural Institute, Naini, Allahabad. It consisted of spike tooth type threshing cylinder 180 degree concave grate top of which was covered with sheet metal. The material is broken by the rotation of spikes and threshed material falls through the concave on the two screen cleaner. The aspiratory blower mounted on the shaft of cylinder is used to suck out the bruised straw. The clean grain comes out of the outlet and is in condition to be marketed directly in the markets. The thresher is operated by a 5 hp electric motor.

The wheat threshers had problem that they could not handle crop with moisture at slightly higher level. When the straw is moist it does not break inside the cylinder chamber. When crop is fed it would get accumulated and get wrapped around rotating parts and choked the machine leading to the overloading of prime mover (motor).

This problem was solved by fitting the chaff cutter type feeding device and mounting the flywheel with blades and beaters inside the chamber for cutting the straw of 1 cm size and using beaters to do the bruising action to be fit for use as animal feed. Thus the chaff cutter attachment helped in overcoming the problem of varying moisture level and also reduced the power consumption as compared to hammer mill type threshers. The 3 types of threshers used for threshing wheat crop are shown in Fig. 6.6 (A-C).

Hammer mill type threshing unit require dry crop for threshing and *bhusa* making, and the chaff cutter type feeder would chop the crop into 1 cm long pieces which will be further bruised inside the threshing chamber. Hence it has the advantage of achieving high output because of chaff cutter type positive feeding device. The Spike tooth unit is suitable for threshing most of the crops by changing the speed of drum and changing the gaps in the concave grate.

All these designs [Fig 6.7 (A-D)] of threshing cylinder configurations are achieving the grain and straw in the form desired by the small farmers. In design (A) the complete straw in undamaged form will be available to the farmer. The crop moisture level may be more for this machine. In design (B) partial bruising of straw will be there however the crop will be fed into the machine in any manner desired. In design (C) the straw is to be bruised completely for use as animal feed. This design requires the dry crop. Design (D) is suitable for gentle threshing of sensitive crops and straw in long and bruised form will be obtained in case the moisture level is high. In dry crop material, the straw will be suitable for direct feeding to the animals.

Grain losses encountered in cross flow threshing units

In conventional threshers of cross flow type the crop passes only once between the rotating cylinder and the concave along the tangential path. Thus the crop is subjected to the threshing action very briefly. Consequently for proper threshing, high threshing cylinder speeds are necessary which increase the grain damage, straw breakage and energy consumption to increase its output. However, high threshing unit output causes high

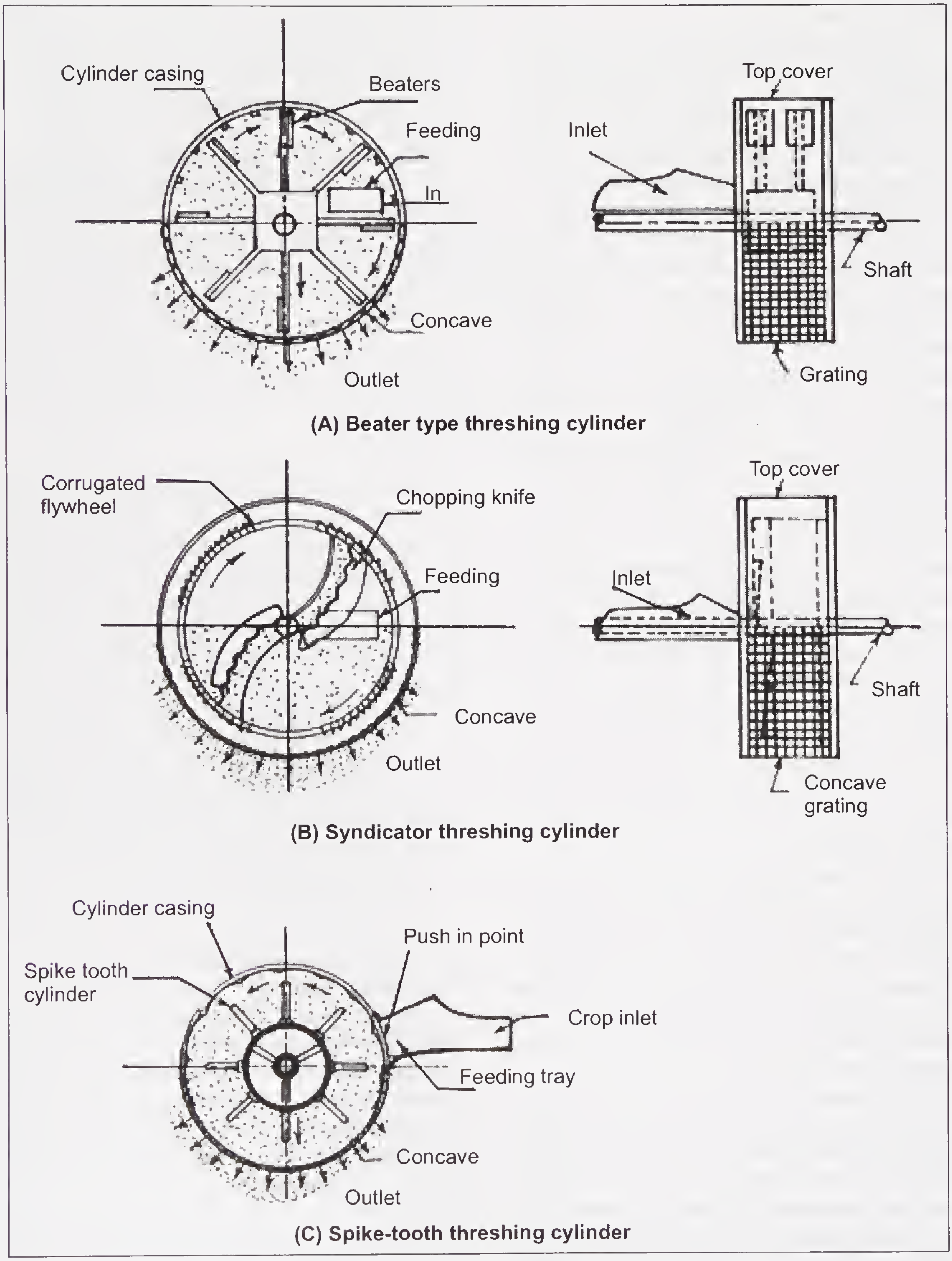

Fig. 6.6. (A-C) Three designs of threshing unit used on Indian wheat threshers.

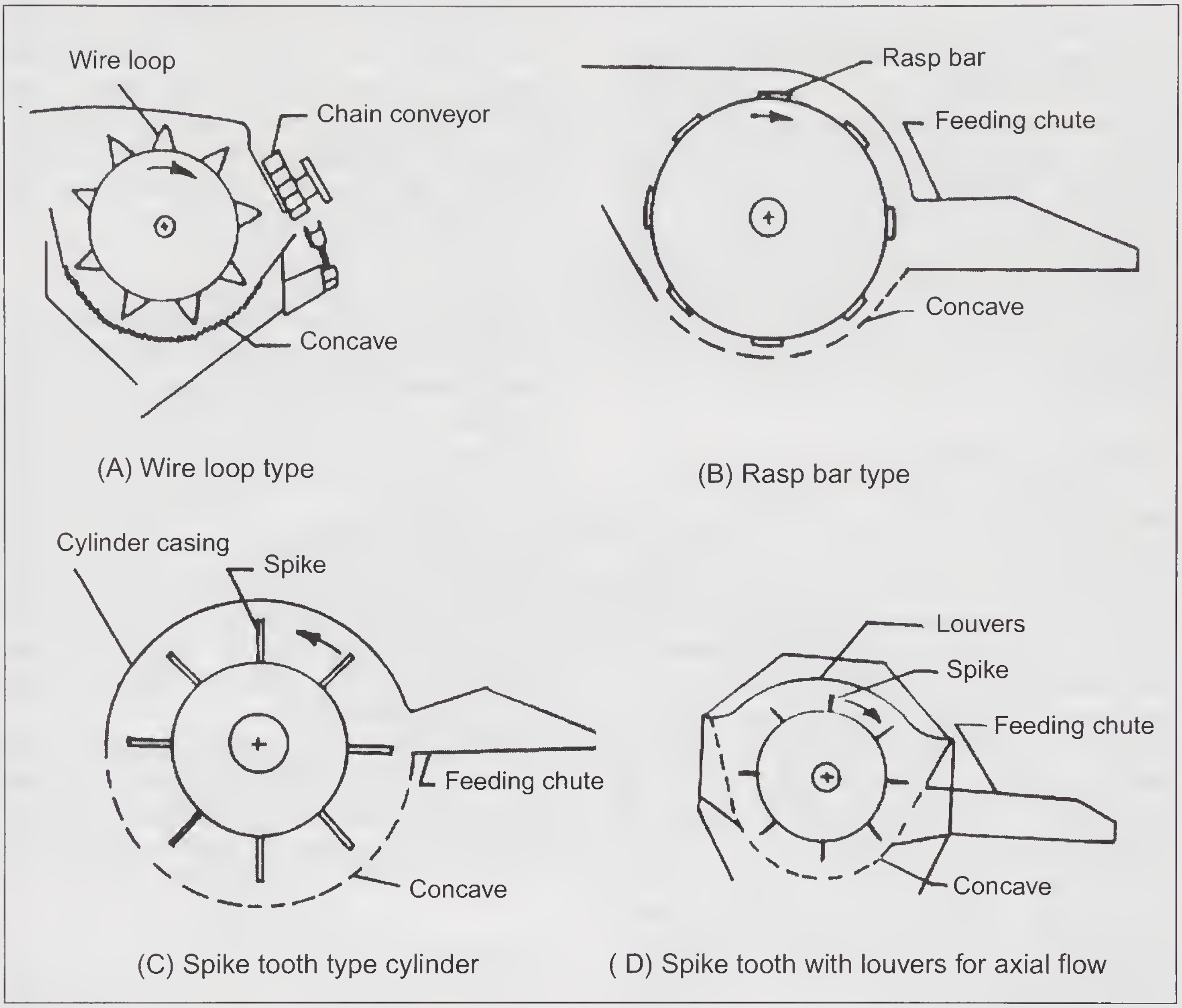

Fig. 6.7. (A-D) Four types of designs of threshing drums used on threshers for different crops in India.

amount of straw with grain to be handled by the straw walkers. The excess of straw fed on straw walkers reduced its capacity of grain separation and thus resulted in high level of straw walker losses. Hence the new method of threshing and separation were studied for threshing and separation of crops.

The combine harvesters manufactured during 1960-75 used rasp bar type threshing cylinders for threshing most of the crops. But for the rice crop spike tooth type cylinders were preferred and for threshing pods type crops angle bar type threshing drums were used. Thus by changing the cylinder speed and concave clearance, most of the crops could be threshed with the combine harvesters. In combine harvesters the threshing units are provided with various adjustments to meet the changing needs of crop and operating conditions. The major adjustments are cylinder speed, concave clearance, sieve opening, chaffer openings, blower output and direction control. Thus the earlier combines using principle of tangential threshing had the grain output capacity up to 15 tonnes/h with 2-3% of losses. The performance depended upon crop conditions, weather and operators skill.

The increase in threshing capacity by

increasing the speed of cylinder resulted in grain losses. It was concluded that losses were due to loss of grain from the straw walker as its performance depended on sifting of grain from the mass of straw. The output of combine harvester depended upon the ability of the straw walker in separating grain from the mass of straw. This involved handlings of huge amount of straw by the combine harvesters and thereby the work on more efficient method of separation of grain from straw was explored during 1964-75 in advanced countries.

Centrifugal threshing

Lamp and Buchele (1963) proposed the use of centrifugal force to obtain impact free threshing and separation during threshing of crop. Lalor and Buchele designed and tested stationary perforated cone with an inner rotor made of eight rubber coated angle bars for the threshing of crop. It was observed that separation efficiency decreased from 27 to 68% as the rotor speed increased from 300 to 500 rpm. Buchanan and Johnson (1965) developed and tested horizontal conical centrifugal thresher unit and separator.

Hamdy *et al.* (1967) concluded that centrifugal threshing was not feasible. Long *et al.* (1969) investigated centrifugal separation and concluded that a continuous flow centrifugal separator was a feasible proposition for future studies and use for threshing crops.

Shrivastava *et al.* (1974) investigated a horizontal conical screen with helical blades on its inner surface and found that the configuration had no potential as a grain separator. A second centrifugal separator consisting of a rotating horizontal cylindrical screen with an auger rotating inside was theoretically analyzed and found capable of separating wheat kernels from the wheat straw.

The harvesting of soybean crop further increased the field losses due to stubble loss and straw walker loss. These losses were more than 4-5% during 1964-65. Thus design modifications were necessary to reduce the threshing and separation losses from straw. The studies conducted showed that the conventional concave and drum with beaters were efficient in separating grain than the straw walker to separate the grain.

Changes in separation system

During this time the manufacturers of combine harvesters installed the grain loss monitor to make operators aware and to reduce the losses to desirable levels on conventional machines. In Germany the combine harvesters were made with four threshing cylinders in line after each other to separate the grain from straw and straw walker was eliminated. The field trials with axial flow threshing system exhibited thoroughness of threshing and separation of grain with the result there was increase in output yield of 4 to 7 % as compared to conventional machines.

The grain damage was also reduced to half in soybean and one third in wheat and sorghum and two thirds in corn as reported. Hence all the attention was diverted to development of axial flow threshing and separating units.

Axial flow threshing (Fig 6.8)

The axial flow of threshing involves movement and advancement of crop through the rotor in a direction parallel to its axis as contrasted to crop passing in perpendicular direction. Thus the longitudinal rotating rotor threshes the grain by combination of impact, rubbing and centrifugal action. The crop passes repeatedly across the concave grates. The action of rotor is gentle but through as the crop moves in helical path over the concave area number of times. Thus threshing action is gentle and more efficient. The peripheral speed of crop straw is about 1/3 the speed of rotor rasp bars. The impeller type feeder also draws the air and dust in with the crop. The rotor cage is funneled shaped front opening with spiral vanes to control the movement

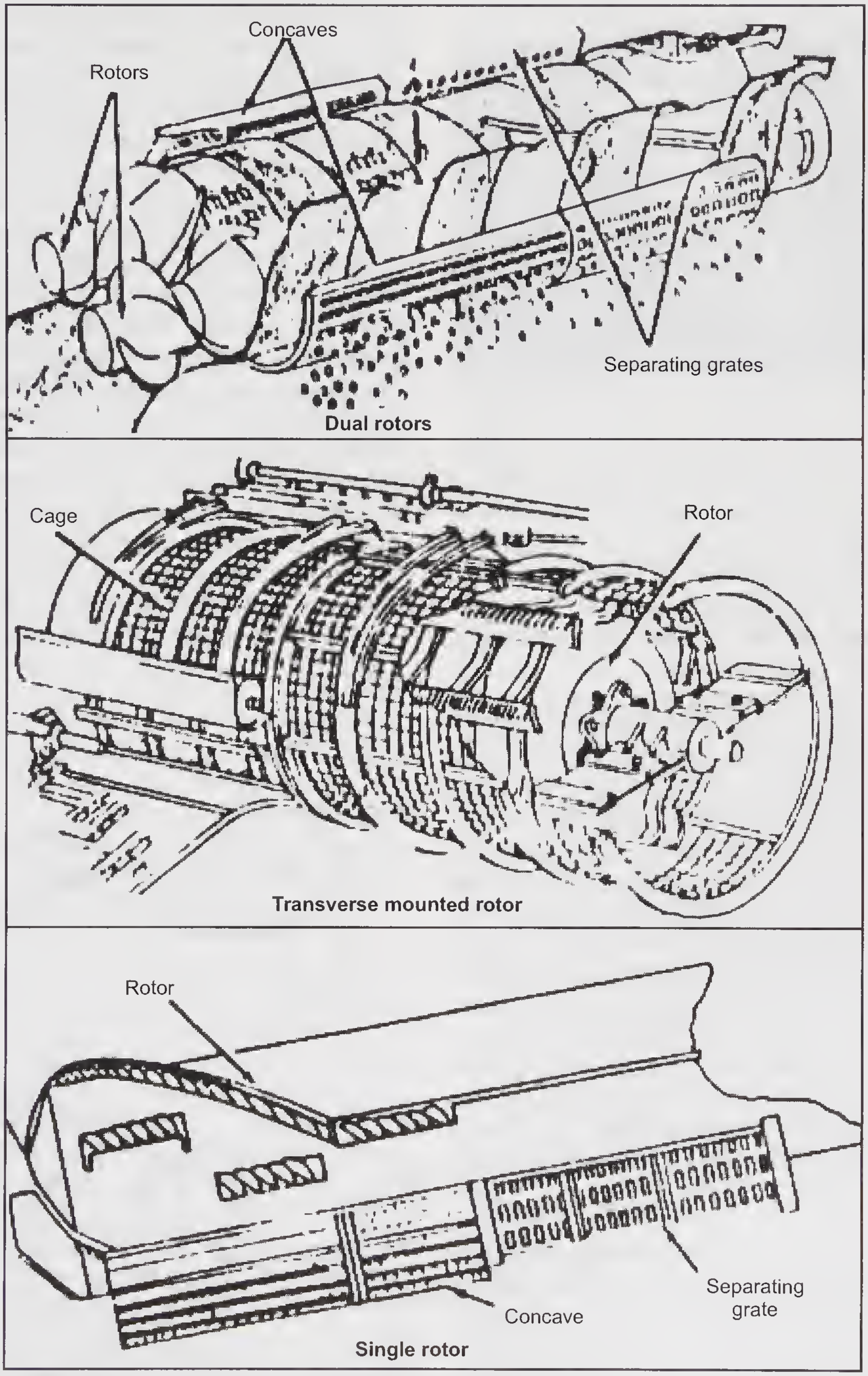

Fig. 6.8. Three designs of axial flow threshing of crops used on combine harvesters.

of material. The bottom of grate is made of grate of wire mesh at the front and grain separating grates just behind. The cleaning unit was modified to suit the new system of threshing. Hence the designers in USA found axial flow threshing as solutions for reducing the losses and enhancing the capacity of the machine. The axial flow threshing used on combine harvesters achieved a very high level of performance by increasing the rate of crop throughput and preserving the grain quality and minimizing the grain losses. This performance increase was achieved due to axial threshing units.

The axial flow design used on combine harvesters is either a single rotor type or twin rotors type. The rasp bars used are similar to the rasp bar cylinder used except the arrangement of the bars on the rotor. In twin rotors the two pairs of rasp bars 180° apart are provided instead of 6 to 8 bars uniformly spaced. On single rotor three bars of helical shape are equally spaced and they move the material along the axis of the rotor. Further there is staggered arrangement of short axial sections between the helical bars. For twin rotors the diameter is 432 mm and for the single rotor the cylinder diameter is in the range of 610 to 762 mm. The concaves are open grate type with adjustable openings and clearances are adjustable. The rotary cylinders are mounted transversely and in some designs they are mounted longitudinally. The rotor speeds are variable for threshing of different crops from 200 to 1600 rpm. The concave clearance is kept high, as the crop has to rotate a few times for threshing of grain. The chances of grain damage are low particularly in crops at high moisture level.

Development of axial flow thresher at IRRI

The engineers at IRRI in Philippines during 1965-68 were interested in development of thresher for the rice crop, capable of threshing rain soaked paddy. It was of small size to be economical for the rice farmers to switch over from the traditional method of threshing. Thus the principle of axial threshing was developed at IRRI (Philippines) first; it was used for threshing of high moisture paddy. The design of thresher was found to be very useful for threshing the wet crop efficiently without grain damage and damage to straw. In axial flow rice threshers, the material being threshed spirals a few times between the threshing cylinder and the concave while it moves along the axis of the threshing cylinder. A set of spiral movement provides a long threshing exposure, permitting more aggressive and versatile threshing and requiring slow cylinder speeds. Such machines damage less grain and work better under adverse threshing conditions such as rice crop at high moisture level. The principle of axial flow for thresher is shown in Fig.6.9 (A-B).

This principle was adopted in all the threshers developed at IRRI for threshing of rice crop. These designs were popularized in

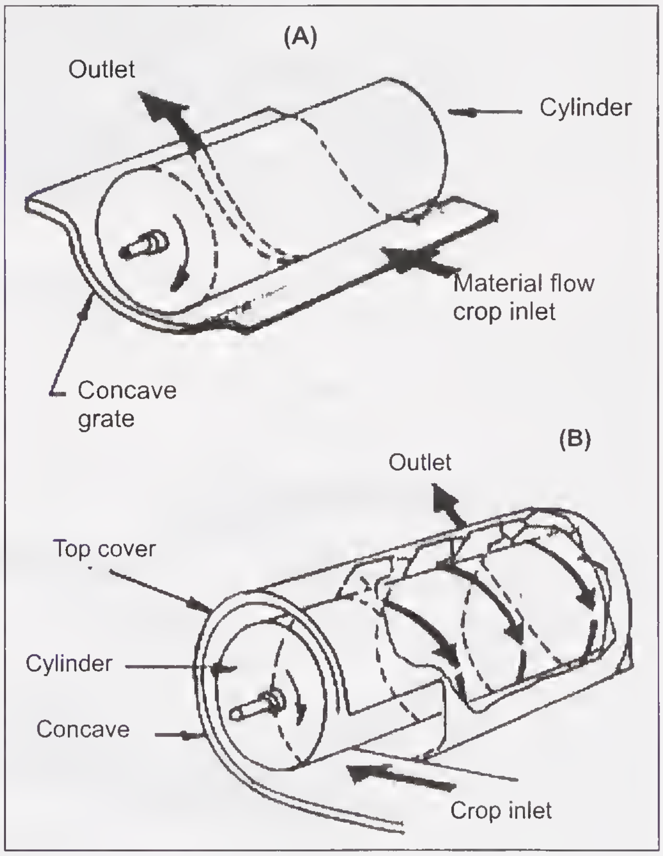

Fig. 6.9. (A-B) The crop movement through (A) cross flows and (B) axial flow threshers.

Asian countries. In USA the threshing units of axial flow type consisting of single and twin rotor type were developed and new types of combines were introduced among the farmers. These were based on the principle of axial flow threshing. The threshing unit consisted of single and twin rotor type cylinders with axis along the length of combine harvester and a large area of concave which helped in recovering most of the grain at the threshing stage, without causing the damage to grain as the operating speed were low as compared to tangential threshing.

This principle of threshing has been used in threshing of crops having seeds of tender type such as soybean and other pulses like black gram, green gram etc. in most of the developing countries.

Whole crop harvester (Fig. 6.10)

The high yield levels of wheat crops were achieved due to improved seeds and agronomic practices during 1970. This resulted in production of huge quantities of wheat straw in wheat producing developed countries. The harvesting of crop on the farm involved the management and handling of straw. The easy method of burning the straw in the field caused the problems of environment pollution and this practice was being adopted in developing countries. Thus to help in better utilization of straw by the farmers in developing countries whole crop harvester was conceived and machine developed.

The concept of whole crop harvesting and threshing was developed at NIAE, UK around 1983. A few machines were evaluated in Asian countries. The idea was to bring in the threshed grain and bruised straw from the field to the farmstead for further cleaning and separation. The machine was developed for the 2.5 to 4.5 tonnes/h and demonstrated but was less acceptable because it involved further operations. It was tractor mounted type requiring high hp tractor to carry the machine load on the three bar linkage. Thus

Fig. 6.10. Whole crop harvester developed for wheat crop for Asian countries.

owner of machine required high powered tractor for its operation. The preliminary trials were conducted in UK, Egypt and Pakistan. Technically the harvester performed the job but was not able to attract farmers' demand in developing countries (Johnson and Matianu 1985).

Stripping type threshers

The Japanese rice crop thresher of hold on type uses the wire loop type cylinders. The wire loops of different shapes are used to increase the threshing efficiency. The separation of paddy grain is from the panicles and is achieved by stripping and impact action. The wire loop cylinders require less energy as compares to rasp bar threshing cylinders. It is because only the panicles are exposed to moving loops while straw is hold in the hand of operator. Thus straw damage was minimum. This type of cylinder can also handle crop with varying moisture level. These threshing units are widely used on threshers and combine harvesters manufactured in Japan. These machines handle only small portion of straw inside the machine. The rice farmers prefer such type of threshers as they utilize the straw for use at farmstead as roofing material and as animal feed. The stripping type threshers are used on most of the Japanese combine harvesters. This type of threshing is also

useful for stripping of groundnut pods from the freshly harvested crop. It can be useful for stripping of pods of pulses like green gram and black gram. The stripping drum can be used for stripping of soybean pods. The main advantage is the low power and energy consumption in this operation.

Grain stripper harvesters from standing crop

At this time the principles of grain stripping from the standing crop in the field were also developed in UK. During 1986 combine harvesters fitted with the stripper heads in the harvesting of wheat crop were evaluated. The view of stripper is shown in Fig. 6.11. It was great concept to harvest only grain but handling straw separately with other machines would have increased the cost of operation. Review of literature indicated that the initial grain strippers were developed in Australia and marketed as Sunshine Harvesters. However the grain stripper developed at UK had the design features with minimum of stripping losses in the field while handling of wheat crop of 7-10 tonnes of grain yield levels per ha.

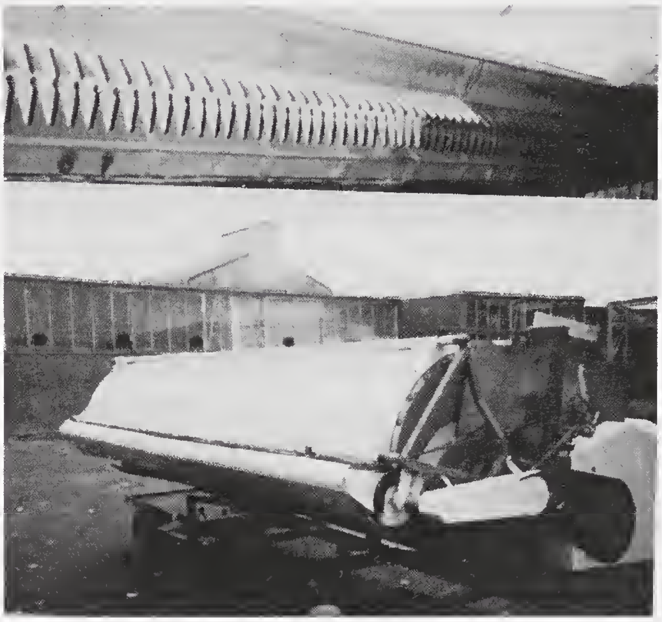

Fig. 6.11. Grain stripping drum for mounting as combine header. Top details of stripping fingers mounted on drum (*Source:* Devnani, NIAE, UK 1986).

The unit developed had the advantage of harvesting grain at a very fast rate and therefore the research on straw incorporation was carried out to make the system workable for the farmers in developing countries.

This principle of stripping harvesting paddy or rice crop was also developed at IRRI Philippines operated by small size power

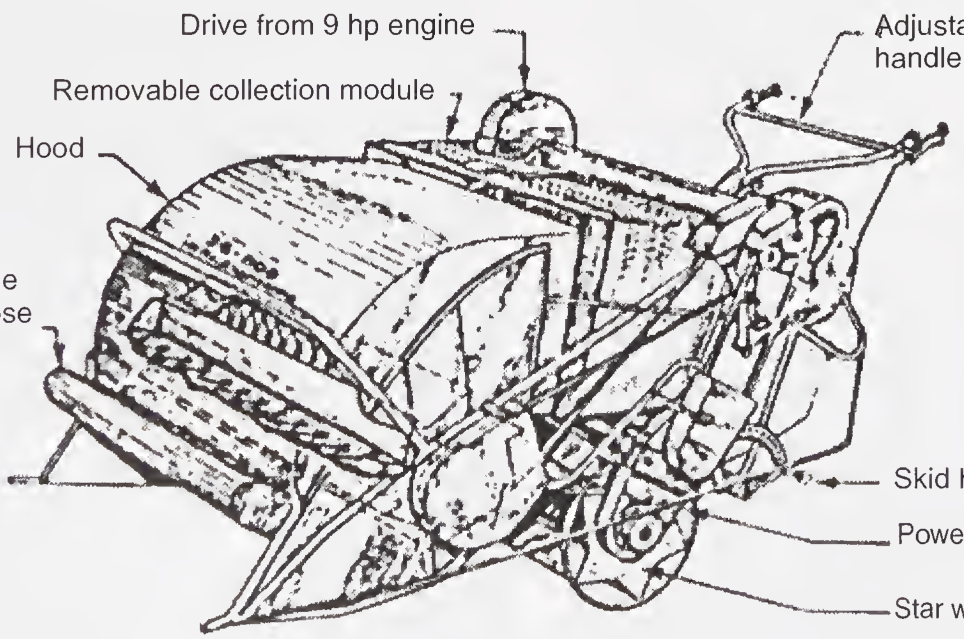

Fig. 6.12. Stripper harvester developed at IRRI for rice crop.

unit in 1993. Republic of China developed and marketed grain stripping type rice harvester (Fig. 6.12). The idea was to develop a lightweight simple design of harvester, which can work in the paddy fields. The unit is self-propelled walk behind type, with grain stripping drum in front and a grain collection tank. It is mounted on wide traction wheels and working width of 750 mm. The weight of unit reported was 300 kg. The interest in this machine was shown by China, Thailand, Indonesia and Sri Lanka.

The basic idea in case of rice stripper was that the rice straw could be incorporated in the soil, as there is plenty of water to get it converted into biomass. However this created the controversy that Asian rice fields are emitting lot of methane gases into the atmosphere. Thus rice crop was creating the problems of environmental pollution. However the farmers in many countries being interested in straw as animal feed had not accepted the technology. The scientists at CRRI, Cuttack, India in 1999 further reported that the methane production and emissions from paddy fields were much lower than reported and estimated by advanced countries.

Development of tractor operated straw combine and straw baler (Fig. 6.13)

During this period in India attention was paid to develop machine to save the straw as animal feed even where combine harvesters were becoming popular. This was because no one was interested in burning of the straw to keep the fields free from straw. Straw was considered important as agriculture and animal raising is the combined activity of farmers. The straw combine consists of four main parts. The straw or stubble cutting and gathering unit, the straw feeding or conveyor, the straw bruising unit and *bhusa* blowing unit. The bruised straw is blown into an attached trolley which is covered with wire mesh. As soon as trolley is filled it is dumped at the straw dumping site normally located in the corner of field. The unit is operated with a 45 hp size tractor. The field capacity of unit is 0.4-0.5 ha/h. The unit is economically viable and cost is also low hence popular with the farmers. The straw balers imported were also evaluated for gathering of straw from the fields. The performance was reported to be satisfactory. However the straw combine had the advantage of low cost of operation and further recovery of grain which had been left in the field by the combine harvesters. The grain recovery of 100kg/ha and straw recovery of 3.0-3.5 tonnes/ha was reported.

Fig. 6.13. Tractor operated straw combine for gathering straw and ears after the use of combine in wheat fields.

Development of Thai rice combine harvester

In Thailand during 1987 the local industry developed the combine harvester based on old European designs and used them for harvesting of rice crop. The number of machines in use was 3000 in 1998. However these machines were not found suitable for combining the crop due to many operational and economic problems.

In 1993 Kalsirislip and Singh reported the performance evaluation of a Thai Rice combine harvester. The details of combine harvester are shown in Fig. 6.14. The machine used the axial flow threshing unit and cleaning unit of blowers and oscillating sieve. The harvester

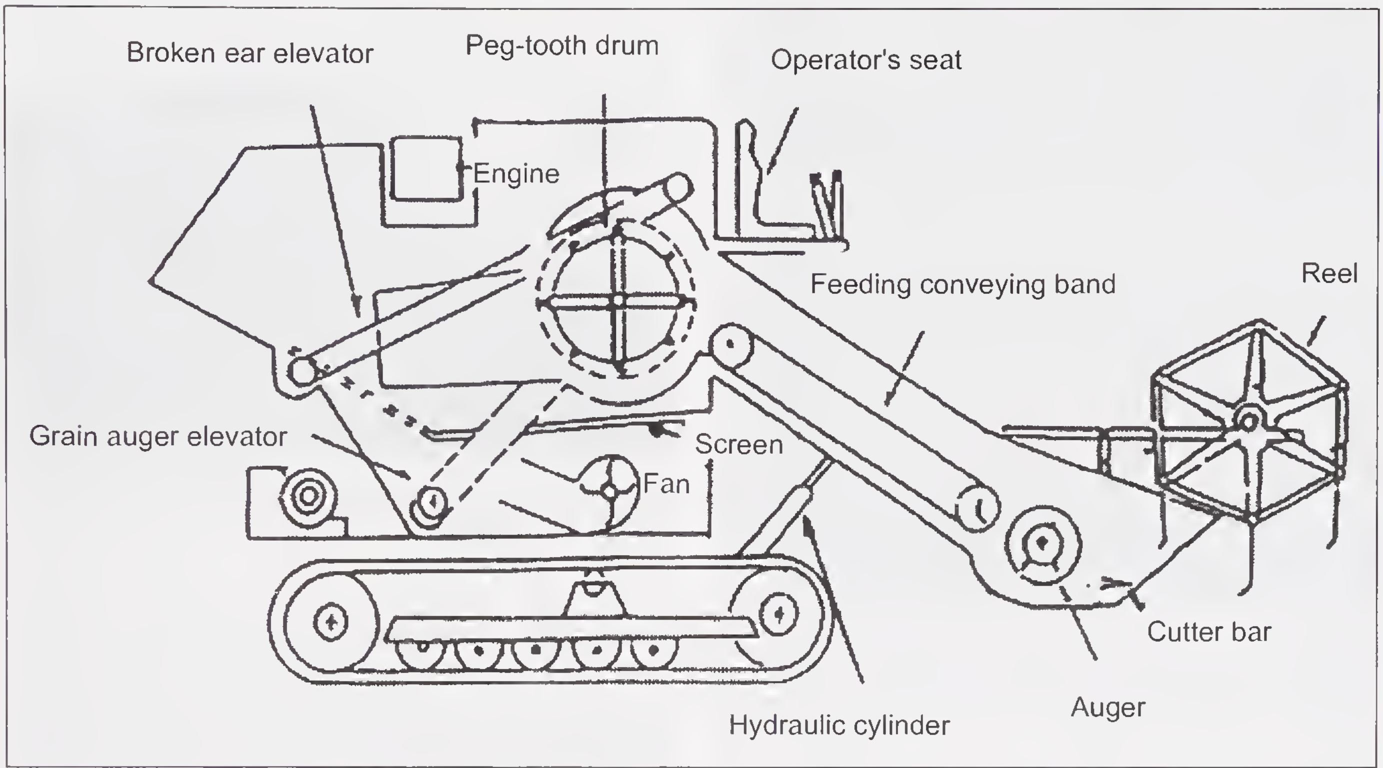

Fig. 6.14. Line diagram of locally made Thai rice combine harvester.

is mounted on tracks to work in soft ground conditions. It is powered by 100 hp diesel engine.

The performance evaluation indicated failure of components of crop gathering and chain conveyor systems. However even with a field capacity of 0.4 to 0.5 ha/h it was reported that the cost of machine harvesting and threshing was lower than the manual methods during 1998.

Vertical axial flow threshing machine

The development of a simple design of vertical conveyor reaper in china during 1980 for harvesting of cereal crops helped many Asian countries to adopt it for the local condition. However Ma Ji in china continued to develop the vertical axial flow thresher for the rice crop. The idea was to combine the reaper and thresher designs to develop the low cost combine harvester suitable for Asian countries. Thus the vertical axial flow threshing machine was developed during 1992-95.

The prototype of VAFT unit with feed rate of 2 kg/sec was made and tested at Prairie Agricultural Machinery Institute at Humboldt, Canada. The machine further developed was semi-mounted tractor type for harvesting of cereals and tested in Beijing around 1999-2000. The Fig. 6.15 shows the sectional view of the VAFT machine. In this machine the threshing cylinder is vertically positioned and is surrounded by concave for 360 degrees. The crop is fed from the lower end of drum and it is threshed by the V type threshing teeth and moved upwards. The U type separating teeth are provided on the drum to completely remove the grains from the straw. The results reported indicated that the thresher can handle the wheat and rice crop efficiently.

Hence axial flow threshing rotor in horizontal, inclined and vertical positions have proved to give the desired performance of machines.

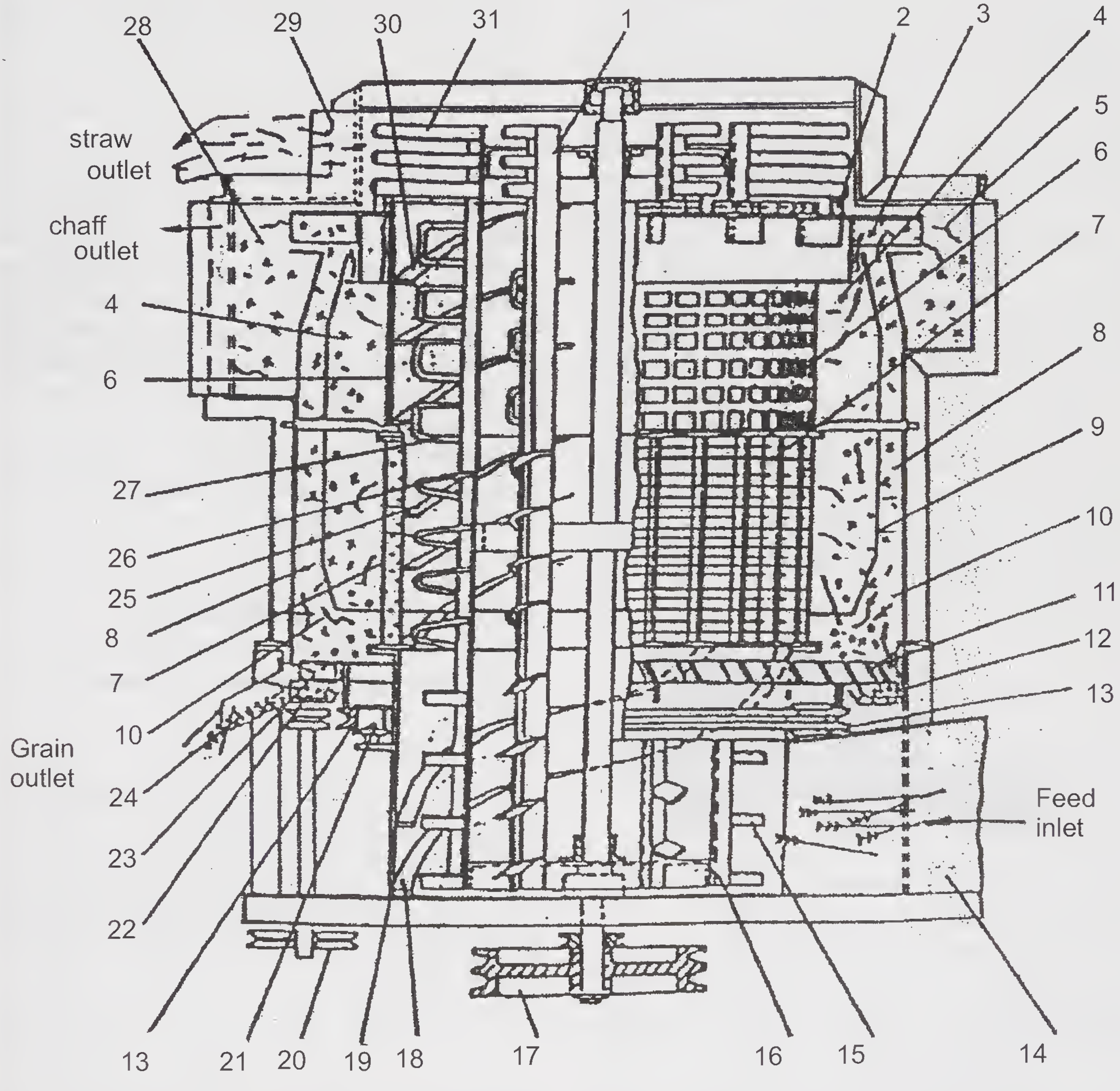

Fig. 6.15. Sectional view of vertical axial flow thresher of high capacity (Ji Ma,2007). 1, Cylinder bar; 2, Fan fixed joint; 3, Hollow-type suction fan; 4, Threshed material compartment; 5, Outlet air channel; 6, Separation concave; 7, Threshing concave; 8, Vertical air duct; 9, Inner wall of air duct; 10, Air entrance; 11, Dispersing wheel; 12, Grain pan; 13, Dispersing wheel drive; 14, Feed opening; 15, Blade feeding teeth; 16, Cylinder assembly; 17, Driving sheave; 18, Feed-chamber loop guide; 19, Feeding chamber; 20, Counter shaft; 21, Roller; 22, Grain scraper; 23, Dispersing blade; 24, Grain outlet; 25, Thresh concave loop guide; 26, V-type threshing teeth; 27, U-type Separating teeth; 28, Chaff outlet; 29, Straw outlet; 30, Separation concave loop guide; 31, Straw through-out teeth

Axial flow model of threshing and separation

The axial flow principle of threshing is important in the present context as the crop yield levels have increased from 4-5 tonnes/ ha to the level of 10-12 tonnes/ha in case of wheat and rice crop. Thus a combine harvester with 5-6 m header has to handle the crop input of 15kg/sec. This is equal to 50 tonnes of crop material per hour. This is at least three times the crop handled by machines during 1970-72. Thus the new designs of threshing and separations are used on combine harvesters to meet the requirement of present day yield levels of crops.

The axial flow threshing system used on combine harvesters is shown in Fig. 6.16. In 1977 DePauw, Francis and Snyder of I. H. Company, USA presented the new designs of combine harvesters based on axial flow threshing and separation.

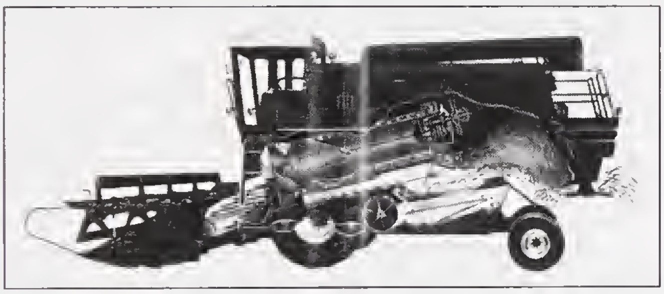

Fig. 6.16. IH Combine harvester fitted with axial flow threshing unit along with cleaning shoe.

The second design was developed with twin rotor type axial flow threshing by the New Holland Co of USA during the same time. These designs of combine harvesters were able to handle crop yield level of 6-8 tonnes/ha or grain threshing capacity of 25 tonnes/h with 2-3 % losses. Thus these designs were able to thresh the crop efficiently and separate the grain from chaff as there are no straw walkers and the space is utilized by long length of cylinder and concave grate area for grain separation with minimum level of losses.

Theory of axial flow threshing: Miu *et al.* (1998) reported the development of comprehensive model of threshing and separation. It was used to predict the value of the process indices by knowing the crop properties, functional details and design parameters of threshing units. The threshing process has been mathematically described by a number of research workers. The model equations quantifying the process indices such as unthreshed grain, free grain, and separated grain in terms of percentage over the length of rotor/cylinder. The threshing and separation losses were predicted over the length of rotor. The performance parameters of axial flow threshing rotor unit are briefly described here

Let x is the variable length of rotor in the threshing unit space, $x \varepsilon$ [0,L].

According to probabilistic theory, the percentage of unthreshed grain s_n in threshing space is given by relation

$$s_n = e^{-\lambda x} \tag{6.1}$$

Where, λ, linear rate of threshing

At the end of threshing length of rotor, the unthreshed grain becomes the threshing loss. (L_t),

$$L_t = e^{-\lambda L} \tag{6.2}$$

Where, L, length of threshing and separating zones of axial threshing unit.

The detached grain from the ears by the threshing cylinder bars and concave become, the free grain s_f in the threshing unit space: It was reported as

$$s_f = \frac{\lambda}{\lambda - \beta} \{e^{-\beta x} - e^{-\lambda x}\} \tag{6.3}$$

Where, β, linear rate of separation; and λ, the linear rate of threshing

At the end of threshing space, the free kernels, which cannot pass through the concave grate, become the separation losses Ls:

$$L_s = \frac{\lambda}{\lambda - \beta} \{e^{-\beta L} - e^{-\lambda L}\} \tag{6.4}$$

The grain separated up to axial distance

x from the front end of the threshing rotor represents the cumulative percentage of grain s_s:

$$s_s = \frac{1}{\lambda - \beta} [\lambda \{1- e^{-\beta x}\} - \beta \{1-e^{-\lambda x}\}] \qquad (6.5)$$

For x, L: we get the maximum percentage of separated grain that is called the cumulated percentage of separated grain.

In terms of statistics the continuous function of cumulative percentage of grain represent a distribution function. By differentiating the function, the appropriate frequency function of grain separation was obtained.

The graphically presentation of unthreshed grain, free grain, cumulative separated grain and frequency function of grain separation was reported by Miu *et al.* (1997) and is shown in Fig. 6.17. The figure clearly shows the relationship of performance indices as the length of rotor increases. It would be noted that the cumulative separated grain is recovered during threshing.

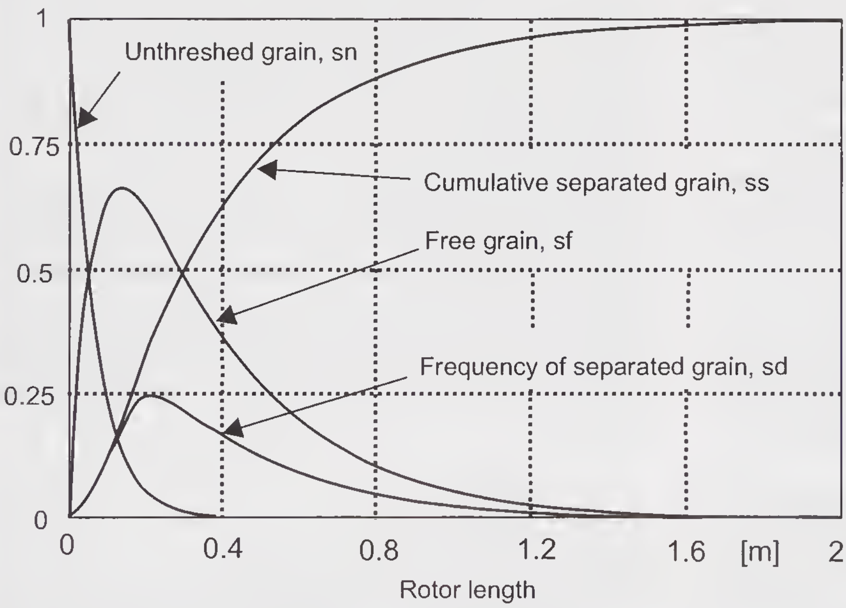

Fig. 6.17. Variation of unthreshed, free, and separated grain verses the rotor length of axial flow threshing unit (Miu, 1997).

In the mathematical model of threshing and separating process the two coefficients used, are λ that represents the linear rate of threshing and β represents the linear rate of separation. Using the physical process analysis and multiple regression technique, the linear rates λ and β are related to following parameters viz. crop, functional and design parameters.

The crop parameters are crop type, variety, moisture content and the bulk density of material other than grain (MOG).

Functional parameters are MOG feed rate, rotor speed and concave clearance.

Design parameters: concave wrap angle, dimensions of concave and cage openings and length of rotor.

In developing the theory for the axial flow threshing following steps were considered: (i) Analysis of the influence of various parameters on grain separation and separation losses; (ii) Analysis of dependence of process indices on values of the coefficients β and λ; (iii) comparison of variation of both these coefficients; (iv) establishing the functions that describe the influence of the parameters on the vales of coefficients; (v) combining these functions in a single function for every coefficient; and (vi) generalization of function for prediction of the value of coefficients β and λ.

The analysis of the values of coefficients β and λ showed these coefficients are in a certain reverse proportional ratio. This means grain separation is proportional with the coefficient that represents the linear rate of separation.

The grain losses are proportional to the coefficient λ that means linear rate of threshing.

It was reported that the coefficient β and λ keep same shapes of the respective curves when a certain functional or design parameter varied for wheat and barley crops. The parameters considered were: (i) Influence of MOG feed rate, (ii) Influence

of rotor speed, (iii) concave clearance, (iv) crop properties and (v) function generalization.

Effect of MOG feed rate: At low material feed rate, the rotating beaters (rasp bars) of rotor drive the thin layer of material quickly, the crop is not compressed sufficiently, and therefore threshing and separation occur later. It means the coefficient λ increases and β decreases. The grain separation improves with increasing the MOG feed rate to increase the material thickness.

At high MOG feed rate the straw layer in the concave clearance is denser; this has the effect of damping the beating energy via the pegs of threshing cylinder, towards the depth of straw layer, consequently the grain separation decreases. The influence of MOG feed rate q on coefficient β and λ establishes exponential dependence and was shown by mathematically relations as

$$\beta = \frac{a.(q_p)^b}{e^{(exq_p)}} \quad (6.6)$$

$$\lambda = \frac{ke^{(m.q_p)}}{(q_p)^n} \quad (6.7)$$

Where, a, b, c, k, m, n are coefficients, q_p, MOG feed rate, e, base of natural logarithms.

In the above relations the $(q_p)^b$, in (6.6) and $(q_p)^n$ in (6.7) have positive influence of MOG feed rate on grain separation.

The relations e^{cxq_p} and e^{mxq_p} have the negative influence of decreasing straw permeability of beating energy across the thickness of crop straw mat at the concave grate.

Effect of rotor speed: The grain separation from ears takes place due to impact forces of cylinder. The greater the speed of rotor the stronger is the action of threshing and greater the centrifugal force and grain separation. Thus increasing the speed of cylinder the grain separation reaches the maximum value as reported by many research workers. At higher speed the stationary time of material in the threshing unit becomes more and more short. Thus the straw permeability decreases because of greater breakup of straw. Thus the value of coefficients β and λ bears exponential relationship with cylinder speed.

$$\beta = a.v/e^{bv} \quad (6.8)$$

and $\lambda = v^2/k.e^{mv}$ (6.9)

where,

v, rotor speed, the a, b, k, m are the coefficients but not necessary same as given previous relations or equations.

v, e^{mv} resulted in positive influence of centrifugal force and threshing action.

v^2, e^{bv} they have negative influence of decreasing crop straw stationary time and straw permeability.

Influence of concave clearance: The effect of concave clearance was given by Miu (1995) in terms of grain separation s_s as follows:

$$s_s = \frac{\zeta.(\delta_i)^n}{(e)^{\zeta.\delta e}} \quad (6.10)$$

δ_i, δe are concave clearances at inlet and outlet. ζ and n are coefficients. At $\delta_i = 0$ the rotor is blocked and the grain separation is $s_s = 0$. The condition represents the choking of the threshing drum.

With increasing concave clearance, grain separation increases until it reaches a maximum and then slowly decreases. The influence on the concave clearance for the coefficient β can be neglected. Thus starting from equation 10 it is found that the coefficient λ is close to

$$\lambda = \frac{k.(\delta e)^m}{e^{(n \times \delta e)}} \quad (6.11)$$

where, k, m, n, are coefficients.

The function in equation (6.11) was built taking into account the $(\delta_e)^m$ which has the negative influence of concave clearance due to decreasing intensity of threshing.

$e^{n \times \delta e}$, has the positive influence of concave clearance due to increasing in the compression

of material, where k, coefficient is dependent on the length of the cylinder or concave.

Effect of crop parameters: The crop parameters that influence the axial flow threshing are (*i*) crop type, variety, and maturity stage; (*ii*) dimensions of the grain; (*iii*) the bulk density of MOG; and (*iv*) MOG moisture content.

The crop properties such as variety and stage of maturity were considered by using the coefficients $k\beta$ and $k\lambda$ in the final formula of the linear rates of β and λ respectively.

According to Wessel (1967) and Huynti (1982) the screening theory, the grain separation in axial threshing unit is assumed that a free kernel will pass through the opening of the concave if the projection of the kernel on the cell surface is within the open area of cell. Thus the formula to compute probability p of kernel passage through concave grate is

$$P = \frac{S_o - \pi \times (d_e/2)^2}{S} \tag{6.12}$$

Where S_o, mean surface area of concave opening; S, mean surface that contains an opening; and d_e, geometric mean diameter of grain kernel as defined by Mohsenin (1978) and Pickett (1988).

A kernel can pass through the concave or the cage. The mean surface of an opening must be computed as a ponderal value of concave and cage opening surfaces, concave wrap angle α angle α_m of the perforated cage as follows:

$$s_o = \frac{s_c.\alpha + s_m \alpha_m}{360} \tag{6.13}$$

where, s_c, surface of concave opening; s_m, surface of cage opening.

According to Miu *et al.* (1997), the coefficient β is proportional with the conditional probability *p* of kernel passage through a cell. The grain separation decreases with increasing of MOG bulk density (free density) ρ_p, because of smaller elasticity and siziness of the straw. Increasing of moisture content of MOG has strong influence on grain separation.

At high moisture level the coefficient of sliding friction between grain and straw increases and the other properties of MOG such as elasticity and size decreases, thus making grain separation difficult and the value of coefficient β decreases.

At low moisture content of MOG due to high fragmentation the probability of kernel passing decreases in passing through the openings. Thus the coefficients β and λ bear exponential relationship with the straw moisture content u_p as follows:

$$\beta = \frac{u_p}{a.e^{bu_p}} \tag{6.14}$$

and,

$$\lambda = \frac{e^{mu_p}}{ku_p} \tag{6.15}$$

where: u_p, MOG moisture content on wet basis; and a,b,k,m are coefficients.

Functions generalization: In the threshing operation there are large number of variables, which affect the rate of threshing and rate of separation of grain. Thus the aim to determine the relation for the generalized coefficients β and λ and to reduce the number of the coefficients for the prediction of the performance.

Using the equations (6) and (15) and a non linear multiple regression technique the values of two compact generalized functions are determined as follows:

$$\beta = k_\beta \rho \left(\frac{vu_p\sqrt{q_p}}{\sqrt{\rho_p}} \times e^{-\{q_p/q_{po} + u_p/u_{pm}\}} \right)^{1/2} \tag{6.16}$$

where, *p*, probability of grain passing through the opening; v, rotor speed, m/s; q_p, MOG feed rate, kg/s; q_{po}, optimum working MOG feed rate, kg/s; u_p, MOG moisture content wet basis, %; u_{pm}, Minimum MOG moisture content (wet basis) %; ρ_p, MOG bulk density

(free density) kg/m³; k_β, coefficient depends on crop type and variety.

The optimum working MOG feed rate represents the MOG feed rate corresponding to the maximum value of cumulated percentage of separated grain for a given axial threshing unit. The value of u_{pm} represents the MOG moisture content corresponding to minimum grain damage when MOG feed rate has q_{po} value. That means the MOG moisture content u_{pm} corresponds to the grain moisture content when the grains are more resistant to dynamic forces of impact. The analysis shows that the coefficient β implicitly depends on the rotor speed (angular velocity) and on the separation surface i.e. rotor diameter and length.

The generalized function of the coefficient λ is:

$$\lambda = k_\lambda \frac{(\rho_p v \delta e)^{1/2}}{\sqrt{q_p}\sqrt{u_p}} e^{[q_p/q_{po}+u_p/u_{pm}-v/v_o]} \tag{6.17}$$

where, k, coefficient that depends on crop and variety; δ_e, exit concave clearance, mm; u_{pM}, maximum MOG moisture content (wet basis) in %; v_o, optimum working rotor speed, m/sec. It represents the rotor speed corresponding to the maximum value of cumulated percentage of separated grain i.e. to optimum feed rate. The above equations have been developed (Miu, *et al.* 1997, 1998, 2000).

The linear rate of threshing is proportional to the specific energy input of the crop and reverse to the transmissibility of the impact energy across the thickness of the crop mat.

Thus the mathematical model of threshing and separation process in axial units uses two coefficients β, the linear rate of separation and λ, linear rate of threshing. The coefficients are in certain reverse proportional ratio. The losses are proportional with the coefficient λ and the variation of the two coefficients in wheat and barley keep some how the same shape when certain design parameter varies. The generalized functions make it possible to predict the process indices: unthreshed grain and separated grain, threshing losses and the separation losses. These indices are related to crop properties, functional parameters and design parameters.

Thus the model is significant for the fact it is based on theoretical relationships and was validated with the laboratory data. The developed model can be used for the purpose of design process for the combine harvesters. It was further noted that the models were verified by conducting laboratory studies on horizontal and inclined axial flow rotors.

It was reported by conducting experiments that axial flow threshing unit having threshing drum 2.0 m in length and a concave grate covering 1.5 m length leaving the portion of feeding zone, was able to achieve high grain separation and low losses even the feed rates were above 25-30 tonnes/h. The losses reported were within 1-2 %.

Thus the methods of threshing and separation had undergone changes during the last sixty years in most of the countries. At present there is a wide range of equipment to meet the requirements of all categories of farmers. It is reported that looking to present needs of farmers in developing countries, they would like to have machine which should harvest the crop completely from the field with little loss and be able to provide grain or seed with no damage and MOG in the form desired by farmers as animal feed or in undamaged form for use at the farm stead or for industrial purpose or production of power in rural areas to maximize the returns for the farmers without causing environment pollution. The use of axial flow threshing principles would be most useful to take care of many crops such as cereals, pulses and oilseeds etc. to bring losses within permissible levels.

❑

7 Maize Shellers

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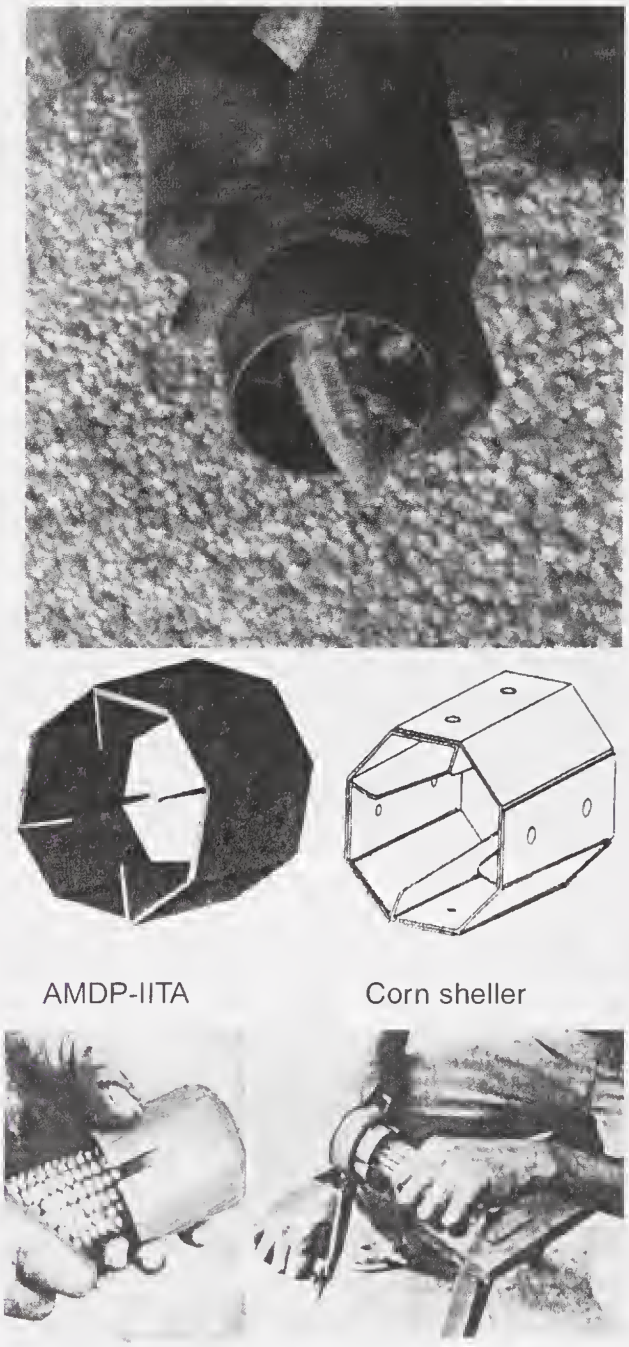
Maize is the important crop grown for grain, fodder or silage. It was introduced in India in the seventeenth century and seeds were brought from USA. Presently this crop with production of three million tonnes covers an area of four million hectares in India. The production and harvesting and threshing methods depend upon the end use of the crop. When it is used for silage or green fodder it is harvested at the appearance of silky hairs and plants are green. In case the crop is used for grain purpose, it is allowed to ripen till the cobs are yellowish and hard. These are stripped from the plant stalks and cobs are dried in the sun. The cobs are husked and shelled manually by beating the cobs with sticks and cleaned manually to obtain the grain. The non-grain mass is normally fed to cattle or animals by the farmers. This traditional method of threshing and shelling is followed by most of the farmers. The major states where maize is grown are Rajasthan, Haryana, Madhya Pradesh, Andhra Pradesh and in hilly regions of India. It is grown during monsoon season where rainfall is less than 40-55 cm. The interest in this crop was revived during the green revolution in India, but the farmers did not accept hybrid varieties from abroad and therefore composite varieties of maize were developed to suit the local conditions under the All India Co-ordinated Project on maize of ICAR, New Delhi. Presently maize is becoming popular in India because of its prime use as poultry, animal feed, and as a snack food by introduction as pop corn in Metros, sweet corn on cob and also popularity of bread from maize flour. For threshing and shelling of crop a number of machines were developed during 1965 to 1980 and are now in commercial production. These are manual type maize shellers, power operated maize shellers and tractor operated shellers, maize cob dehusker, pedal operated dehusker cum shellers, husker shellers and multi-crop threshers suitable for threshing of maize crop.

Manual maize shellers

The manual type maize sheller were introduced in the country during 1979-80 by the ICAR Research Complex for North East Hill Region at Shillong, Meghalaya among the farmers by the agricultural engineering group and then it was modified, multiplied at the Central Institute of Agricultural Engineering, Bhopal and through the prototype production centres of All India Co-ordinated Project on Farm Implement and Machinery of ICAR, New Delhi.

There are two types of designs developed at CIAE Bhopal made of pipe section fitted with four tapered angle shaped ribs equi-spaced inside the tube. These ribs are riveted and given slight inclination. The cob is taken in one hand and the tube in the other. By rotating the cob and tube the grains are shelled out from the cob. The device is capable of shelling cobs completely and can be operated by man, woman, boy or girl easily to do the shelling of maize.

The agricultural engineering department of Rajendra Agricultural University, Samstipur, Bihar developed a maize sheller from a 20-gauge G.I. sheet of 20 cm and 10 cm size, which is rolled into cylindrical shape of 6 cm diameter with 10 cm length. The four rows of V shaped notches are cut along the length and these notches are inverted inside the pipe at 90-degree angle. These notches are used to shell the cobs by rotating the cob inside the tubular sheller. The size of notches is small and it increases to take care of small and big size cobs normally produced in that region.The tubular maize shellers were also developed in the RNAM participating countries and Philippines and a few designs are shown in Fig. 7.1. The latest designs incorporate the change in the shape of tube and are made as octagonal shaped. The change in material used has also been changed by many manufacturers. From metallic shellers to presently made from plastics to make a light weight unit and convenient for use by the



Top-shellers developed at CIAE; *Bottom*-Corn shellers of AMDP, Philippines

Fig. 7.1. Tubular maize shellers used in Asian countries.

woman workers. The output of these devices is 8-15 kg/h and the cost of unit is ₹ 30-50 (US $ 1.0 approximately).

Hand operated single cob maize sheller – table or bench type (Fig. 7.2,7.3): The hand-operated sheller consists of a circular disc with

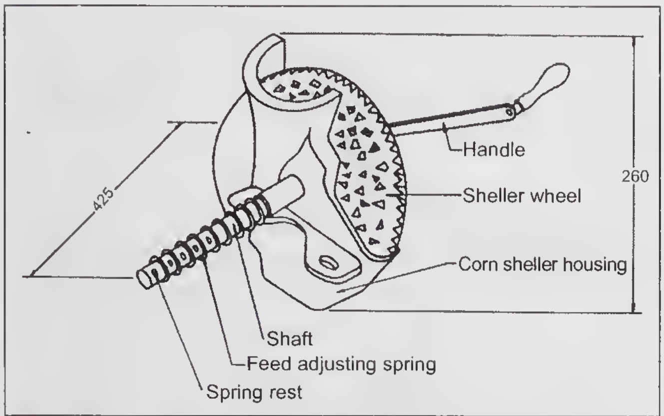


Fig. 7.2. Single cob maize sheller bench type used in India and Nepal.

spikes of 12 mm in size cast along the surface. At the centre is provided a shaft with a handle for rotating the disc. On the side of disc is fitted a cast iron shaped frame piece with cob inlet and outlet at the lower end. The piece is stationary but spring loaded so that it helps in feeding the cobs of different sizes towards the disc and allows the cob to slide down during the motion of disc. The spikes on the disc shell out the grains during its rotation. The rotation of disc makes cob to rotate along its surface and thus most of the grains are shelled out. The cob heart comes out at the outer end. The design is very simple and is a low cost device. It has output of 15-25 kg/h per worker. The unit is lightweight. It is also popular in maize areas. The unit was introduced in India during 1962-64.

The hand operated maize sheller of gear type consists of the disc with spikes on its surface. Instead of a cast iron piece attached as shown in bench type device a bevel gear of automotive differential is mounted in front of it with the gap of 15-20 mm between the disc and the gear. On the top a feed hopper with cob inlet support is provided to direct the cobs in between the disc and the gear. The rough surface of disc and teeth of gear help in shelling the kernels from the cob. The gear also moves the cob downward as it is rotated and makes the cob to rotate and thus the kernels are removed. As soon as cob starts to move up on the disc the kernels have been removed

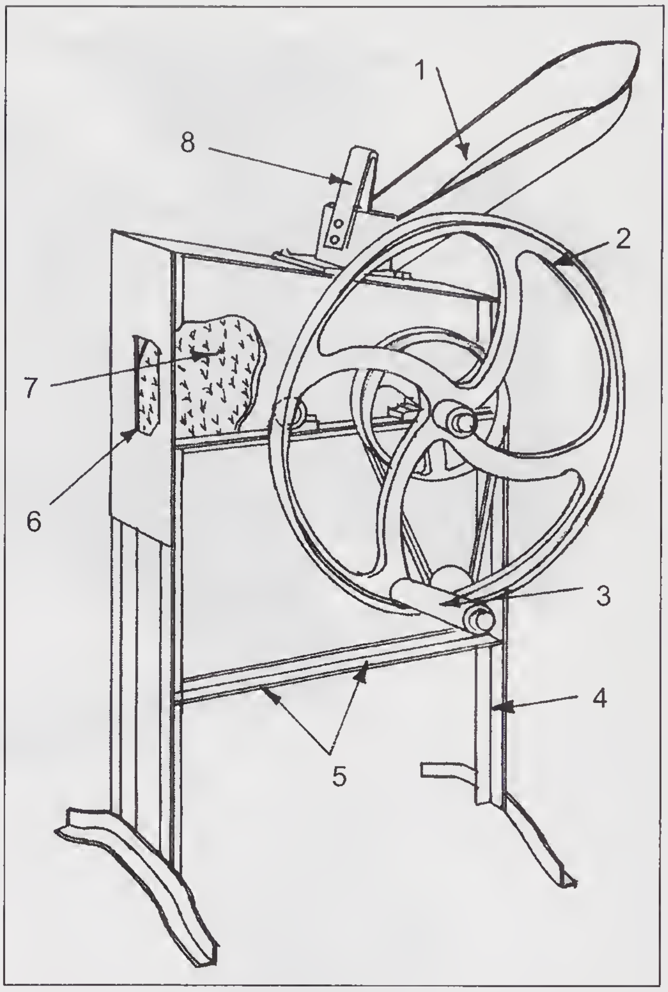


Fig. 7.3. Hand operated maize sheller of gear type. 1, Feeding tray; 2, Flywheel; 3, Operating handle; 4, Frame; 5, Grain outlet; 6, Cob heart outlet; 7, Shelling disc; and 8, Feed control.

and the pithy heart of cob is ejected out of the machine.

The unit is provided with m.s angle iron frame and handle for the operation.

Power operated sheller (Fig. 7.4)

The maize sheller consists of a feed hopper, a compression spring, a bevel gear fixed adjacent to a shelling disc, which pulls the cobs inside, while a spring-loaded tongue, which is provided above the bevel gear, holds the cob tight against the shelling disc. The rotating disc accomplishes shelling. Blower separates the chaff from the kernels. For getting efficient performance it is advisable to sort the cobs according to the size i.e. diameter

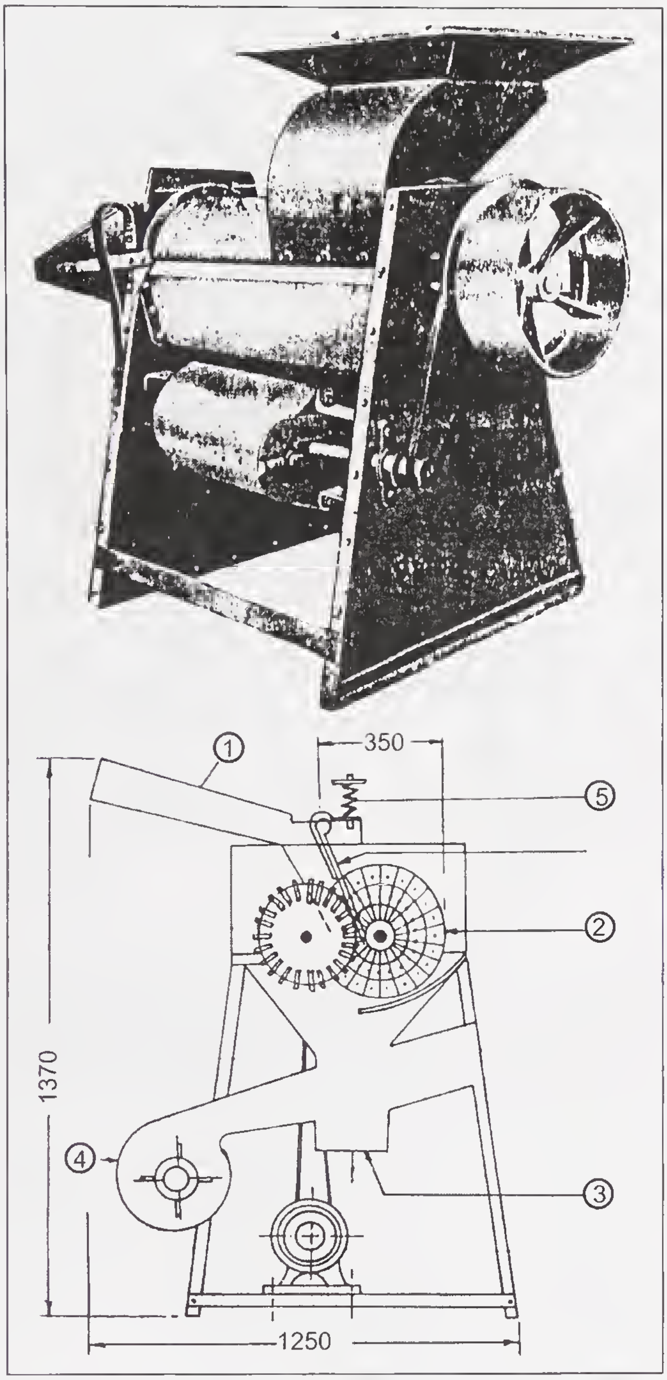


Fig. 7.4. Power operated maize sheller (cylinder with lugs type) tractor and motor operated. 1, Feeding table; 2, Threshing cylinder; 3, Immature grain outlet; 4, Blower; 5, Spring.

into different sizes before shelling. The spring is adjusted to suit the size of cob being shelled. The machine is made for manual operation and also for operation with electric motor of 1 hp. The output of motorized unit is 250 to 300 kg/h. The unit was developed at TNAU Coimbatore. The Rajasthan state agro industries corporation, Jaipur, India commercially produced such maize shellers during 1974-78.

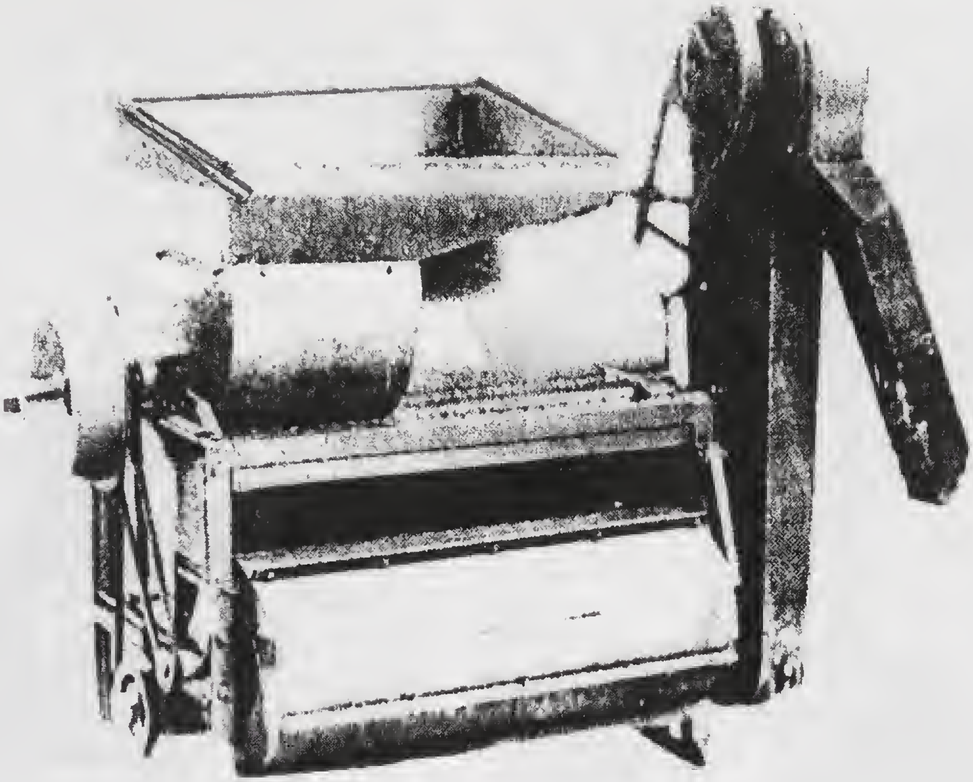
Maize shellers in asian countries

The maize shellers operated by diesel or petrol engines were also developed in many Regional Network for Agricultural Machinery (RNAM) countries such as Philippines, Thailand and Indonesia. These machines have output capacity of 1,000 kg/h with a 5

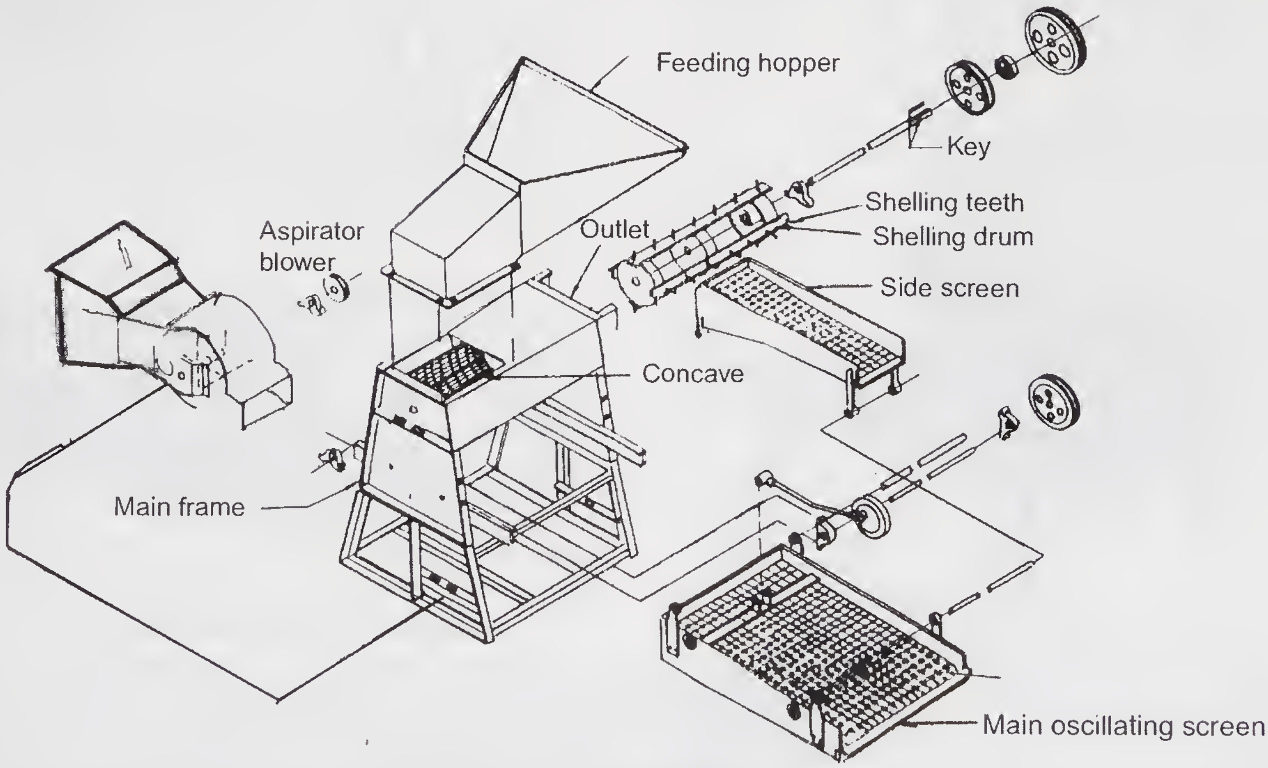
Fig. 7.5. Maize sheller developed in Philippines.

hp power unit consuming approximately 1.0 litres of fuel /h. These are shown in Fig. 7.5 and 7.6 (A-B).

The farmers in India and Asian countries harvest crop when it is dry and the husk have turned yellow, which is around 10-11 per cent. At this level; the kernel damage during shelling is very low. By harvesting maize crop at higher moisture level the farmers can have more yield levels. The sun drying of crop in the field subjects the cobs to the field infestations with eggs of the insects and pests. The untimely rain can raise the moisture level to allow harmful fungus growth in the cobs. Though field infestation is not visible to the naked eye, but the storage of grain in storage bin can cause very severe grain damage within a period of few months. The recommendation of harvesting and shelling followed by drying to safe moisture level can help farmer to have



A. Maize sheller manufactured in Republic of South Korea fitted with shelled grain lifter



B. Maize sheller manufactured in Thailand

Fig. 7.6. (A-B) A few designs of power operated maize shellers developed in Asian countries.

more grain and of high quality if the harvest and post harvest recommendations are followed.

Shelling at high moisture level

The most recent design of sheller has been reported from Indonesia (Tastra, 2009). The farmers wanted machine which should shell the maize cobs at higher moisture level, should have low grain damage and the cobs should not be broken as these are used as fuel. Tastra reported that the grain or kernel

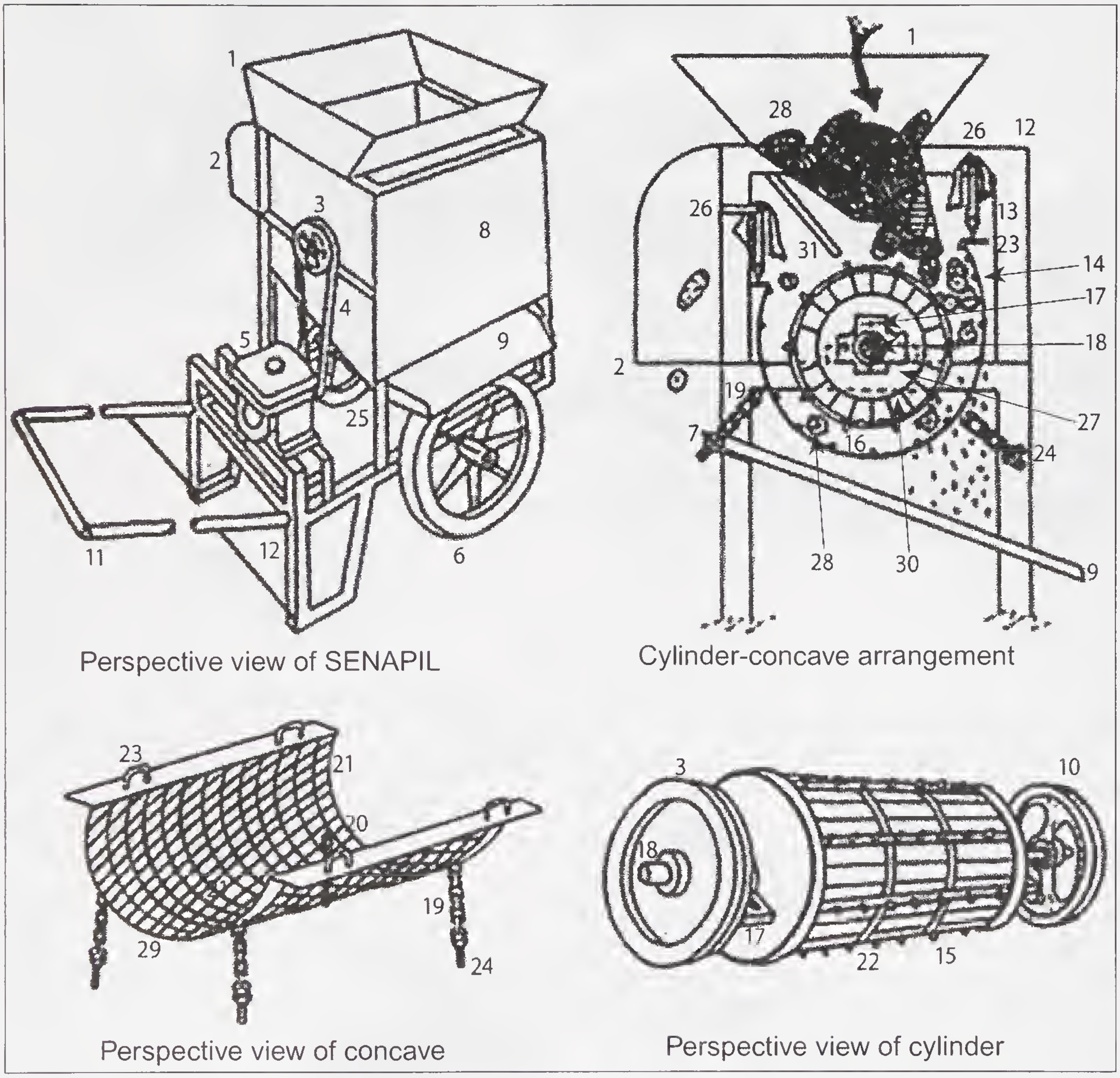


Fig. 7.7. Schematic design of Senapil sheller developed for shelling high moisture maize. 1. Hopper; 2. Cob outlet; 3. Pulley diameter 230 mm; 4. Y belt B type; 5. Gasoline engine (7 hp); 6. Wheels; 7. Component of setting concave; 8. Front concave; 9. Grain outlet; 10. Flywheel; 11. Handle; 12. Machine frame; 13. Rubber spring; 14. Concave; 15. Shelling teeth; 16. Cylinder; 17. Lager; 18. As dis. 19 mm; 19. Chain; 20. Curved strip metal; 21. Curved iron rod; 23. Hook; 24. Bold; 25. Pulley diameter 127 mm; 26. Hook; 27. Strip plate; 28. Husked cop; 29. Iron rod; 30. Wooden cylinder; 31. Cob resistor.

damage is due to sheller where concave is rigidly fixed on the frame. The studies were conducted to reduce the grain damage and broken cobs. Thus main aim was to reduce the normal stress during shelling process. This was achieved by developing a concave system that vibrates without causing impact load on the grains.

The developed concave uses rubber spring suspension to minimize the impact forces and allows the cobs to align along the axis of cylinder thus the breakage of cob heart is also not there. The prototype developed in Indonesia is called Senapil. It is operated by 6.5 hp diesel engine. The performance tests indicated the output capacity of 4.82 tonnes/h for maize at 24 % moisture content. The grain damage at this crop conditions was 5.0% and breakage of cob hearts was 35.1% as compared to 96.6% in locally manufactured machines. The grain output of local shellers of same powered units was 2.57 tonnes/h and grain damage of 12.33%.

Thus sheller was able to achieve output of 600 – 700 kg/h/hp. This is more than four times on the basis of power input as compared with the output from the available machines. The cost of operation was also reduced. The schematic arrangement of sheller is shown in Fig. 7.7.

Dehusking of maize cobs

The dehusker sheller consists of a dehusking unit and a shelling unit. It is operated manually. Two persons are used to pedal the machine and one operator to feed the cobs. The dehusking unit consists of one steel roller and one rubber roller. Here the husks are removed and dehusked cobs are fed into the shelling unit. This consists of a rasp bar cylinder and a concave. The grain and fine are collected below the concave and are cleaned afterwards. This machine was developed during the period when there was no electricity available in many hilly areas of Rajasthan.

Fig. 7.8. Power operated maize cob dehusker developed at Udaipur (1975).

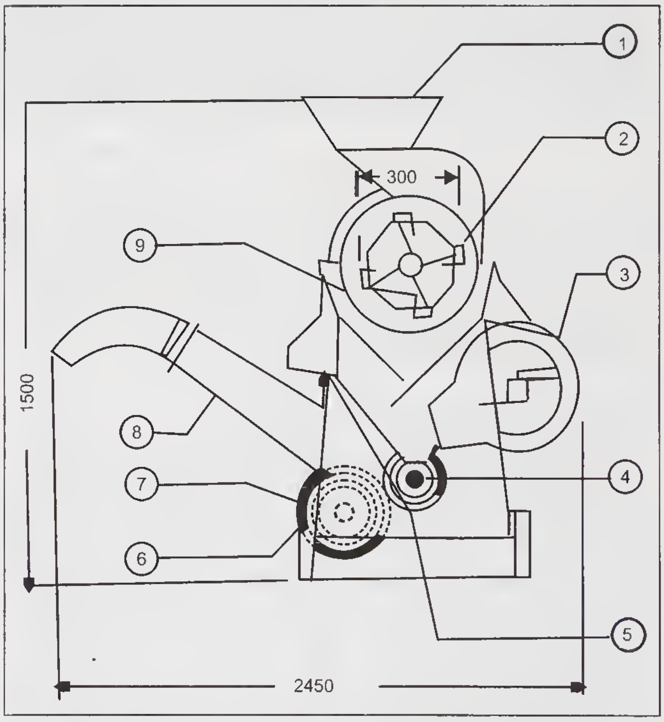


Fig. 7.9. Maize husker sheller (TNAU design). 1, Feed hopper; 2, Rotor or cylinder; 3, Blower; 4, Grain auger; 5, Augur casing; 6, Frame; 7, Motor; 8, grain blower; and 9, Concave sieve.

Power operated dehusker (Fig. 7.8, 7.9): The maize cob dehusker consists of a feeding hopper, a dehusking bed, husk-discharging unit; cobs discharge chute and a power unit. The dehusking unit consists of a pair of rollers, a rubber roller of 100 mm diameter and 1,020 mm long and the other roller is a steel roller of 77 mm G.I. pipe over which are welded 10 mm

rods over the periphery to provide the rough surface. On this pipe is welded mild steel rod of 10 mm diameter in spiral form with 125 mm pitch. Over the periphery of this pipe type roller are welded the triangular shaped spikes to provide positive hold on the husks while removing them from the cobs. The spiral rod on the pipe makes the maize cobs move towards the other end. Here a discharge chute is provided to discharge the dehusked cobs. The output of unit was 500 kg/h and is operated with a motor of 5 hp. The weight of unit is 150 kg.

The unit consists of a hopper, a rotor, a sieve, a blower, auger and an elevator. The unit is fed with cobs with husks in the machine. The removal of cob sheath and the shelling of grain take place during the rotation of rotor and movement of cobs along the sieve. The shelled kernels fall from the sieve and are carried to one end of machine and then elevated for bagging. The shelling efficiency of machine was reported as 98%. The unit is capable of handling dry cobs.

Multi-crop thresher for maize

Maize crop has been successfully shelled with the CIAE multicrop thresher by making changes to suit the size of maize cobs and also to make changes in the size of sieves. The speed of operation of the spike tooth cylinder is also set for the crop being shelled. The speed recommended is 9-10 mps. The concave clearance of 25-30 mm is recommended. The size of top sieve in the cleaning shoe is provided with 12 mm holes. With these adjustments the crop of cobs were shelled at the rate of 400 kg/h with the 5 hp size unit.

Mechanical damage in shelling maize cobs

Sheller shells the maize cobs manually and as the speeds are low the chances of seed damage are negligible. When shelled by power operated units the cobs are subjected to cylinder speeds while it is being shelled therefore subjected to seed damage.

Mahmoud and Buchele (1975) found that cobs axis parallel to cylinder axis orientation suffered the least damage at all moisture level followed by the ears fed randomly to the cylinder. The highest damage is suffered when cobs are fed with their axis perpendicular to the cylinder. Therefore it will be noted in the design of maize shellers of power operated type the feeding hopper is designed such that the orientation of cobs is in the direction of cylinder axis. It was reported that minimum damage was at 20 to 22 % moisture level. The kernel damage increased with increase in cylinder speed and moisture content. The damage is minimum at the speed of 7-9 mps. At higher speed of 12.8 and 18.7 mps for the laboratory sheller the damage was between 26.3 and 42 %. But the average germination was 88.6 %. It was reported that the germination of all the kernels having breaks, cracks or other injuries in the seed coat decreased highly.

The farmers in Asian countries raise maize crop as coarse grain and is also consumed by people and animals. The crop is also raised as fodder crop to feed the cattle. The demand for maize has increased due to increase in population of poultry birds. The maize is used as poultry feed. For the small farmers with area under crop of less than a hectare a manual or pedal operated sheller will be useful. However in a village, which is raising maize as the main crop, the power-operated unit would be very useful. In areas where crop rotation followed is Maize- wheat; the farmers can use the multicrop thresher for the both crops. The power-operated design for shelling maize at high moisture level of 24 % has also been developed and reported.

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8 Threshing of Coarse Cereals

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Threshing of sorghum

The coarse cereals such as sorghum, pearl millet and millet are grown under the arid and semiarid regions of India. The total production of coarse cereals has increased to 30 million tonnes during 2000. The sorghum is the main coarse cereal raised in many states of India and the yield levels have increased continuously for the last 50 years. The 50% of total sorghum is produced in the state of Maharashtra. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, is engaged in developing the new cropping systems for the semi-arid regions of India. The new hybrid varieties of sorghum and millets suitable for the arid regions of the country was released. The varieties of crops like chickpea and pigeon pea suitable for arid regions have been introduced. Therefore the need for the suitable thresher of multicrop type to thresh above-mentioned crops was felt.

The IRRI axial flow thresher (Fig. 8.1) for rice of portable type and other model with cleaning units along with the local thresher were evaluated by Singhal and Thierstein (1987). The evaluation report on threshers for threshing of sorghum, millets, chickpea and pigeon pea were reported. The need for sorghum thresher was felt because it was reported that certain genotypes of sorghum and millets are difficult to thresh at a moisture content of 15 % and more, which is common at the time of harvest. When the sorghum is threshed at high moisture levels their glumes 5 to 15 % are retained with grain and therefore quality of grain is reduced. The threshers tested were axial flow thresher (portable) and IRRI thresher with cleaning system, Alvan Blanch Midget thresher (Fig. 8.2) without cleaning unit and LCT thresher (Fig. 8.3) with rasp bar threshing cylinder with concave with cleaning and separating system. These were selected for threshing sorghum and millet crops. The performance of threshers is reported in Table 8.1.

The IRRI axial flow threshers are mostly designed for threshing of rice crop at high moisture content. The unit with cleaning system is again designed for use on rice crop. Alvan Blanch Midget thresher is for threshing rice crop, as it has no cleaning system. LCT thresher is a multicrop thresher based on rasp

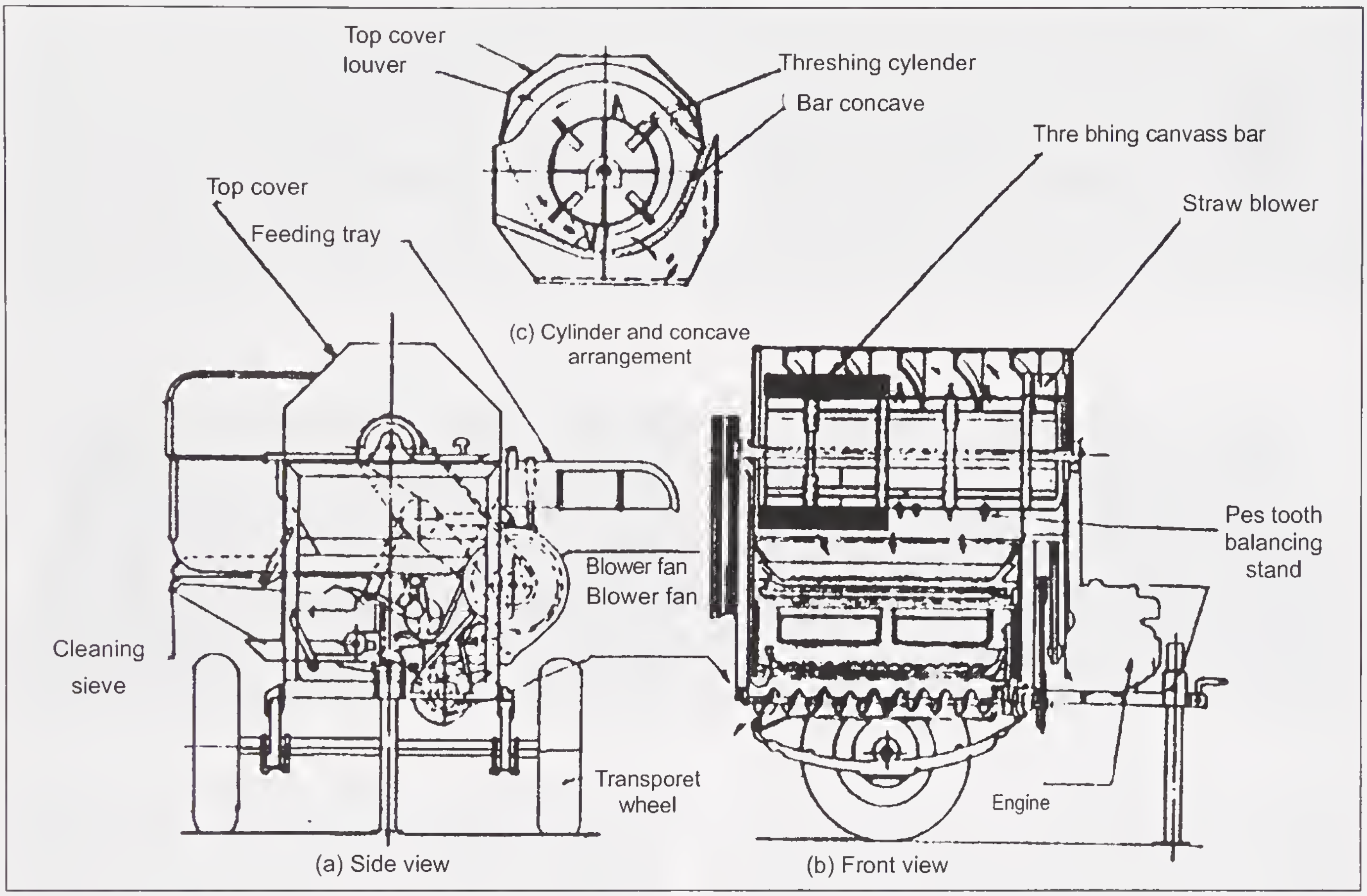

Fig. 8.1. IRRI axial flow thresher tested for sorghum and millet.

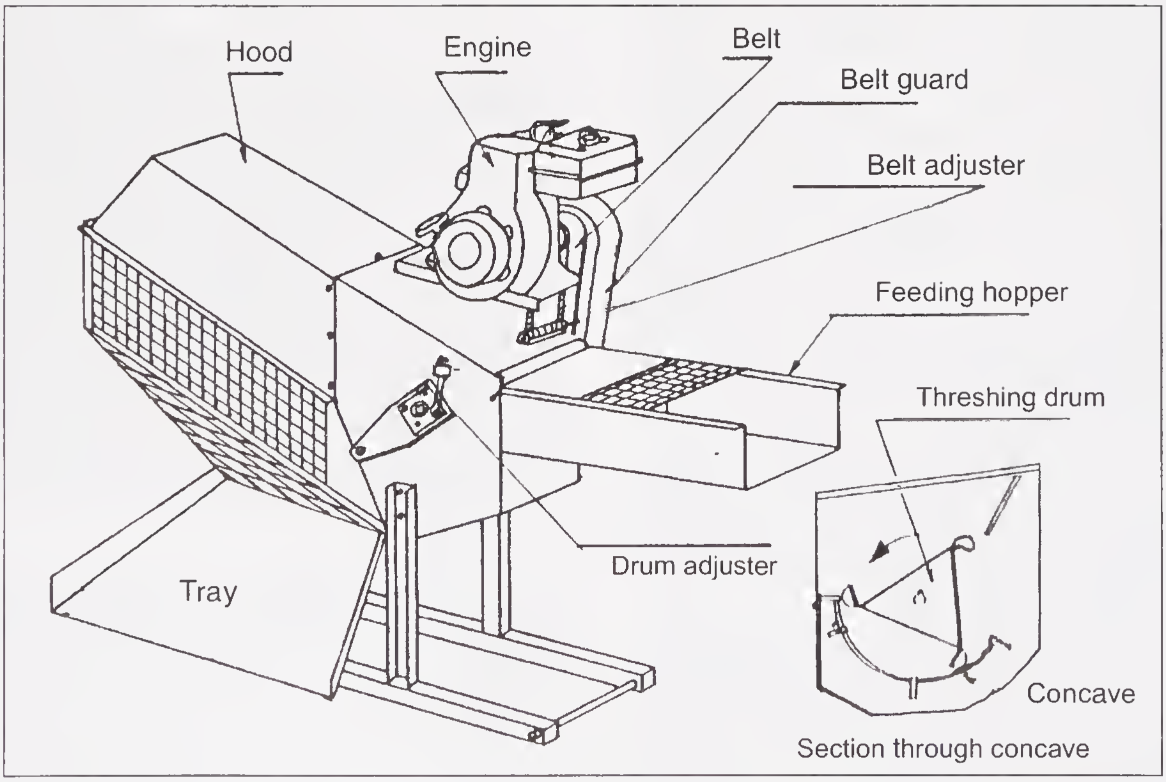

Fig. 8.2. Small rasp bar type rice thresher. (Alvan Blanch Midget thresher).

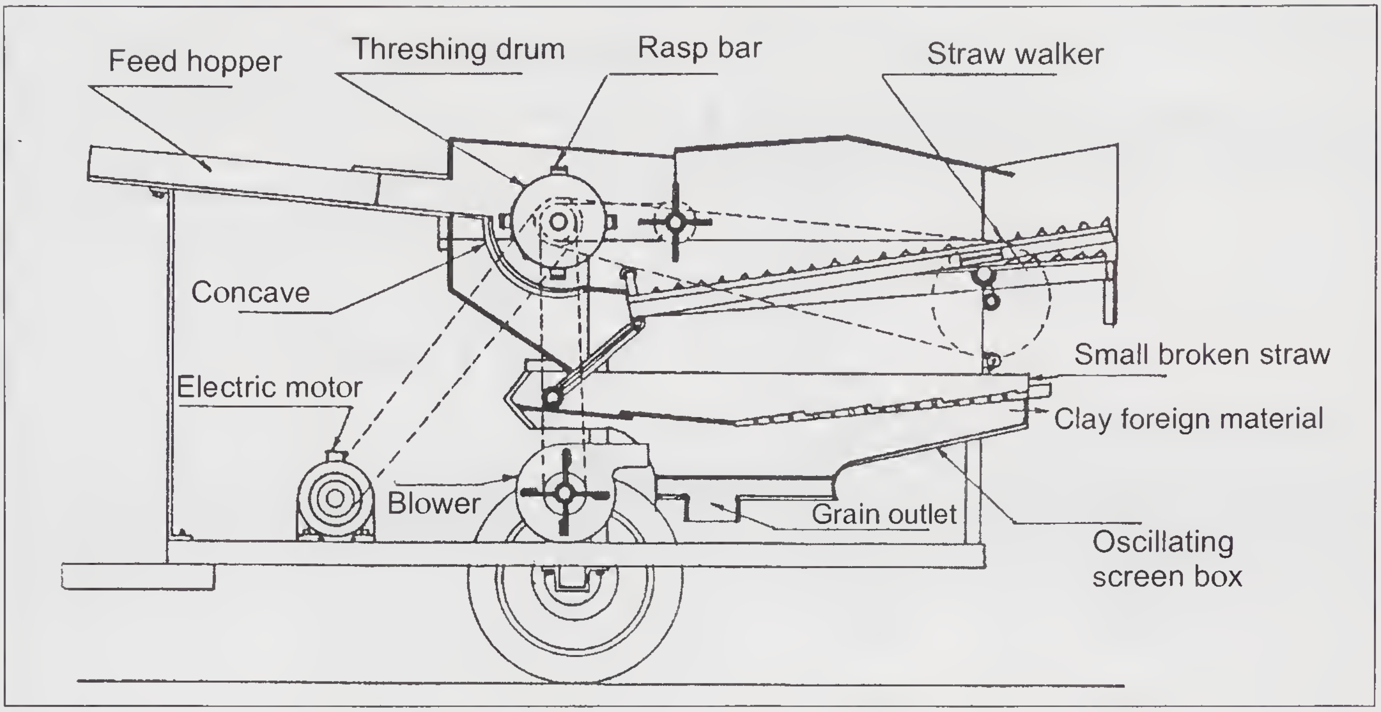

Fig. 8.3. Multicrop cross flow LCT Thresher.

Table 8.1. Performance of four threshers on threshing of sorghum and millet at grain moisture level of 10-12%

Thresher	Threshing efficiency %	Broken %	Separation loss %	Cleaning efficiency	Grain output kg/h	Energy required KWh/tonne
Sorghum (CHS 6)						
IRRI axial flow portable	82	0.3	5.0	-	210	16
IRRI axial flow, with cleaner	89	0.7	4.7	92	740	10
Alvan Blanch Midget	82	0.4	-	-	73	30
LCT thresher	98	5.5	-	96	1,000	15
Millet (BJ 104)						
IRRI portable	76	0.2	12.1	-	176	18
IRRI axial flow with cleaner	80	0.6	3.5	86	480	16
Alvan Blanch Midget thresher	62	0.2	8.1	-	80	30
LCT thresher	80	2.0	-	63	600	20

bar threshing cylinder and cleaning unit is provided with blower and sieves to clean the threshed rice crop. Thus the performance of LCT thresher was satisfactory for threshing of sorghum only. In threshing of millets, the threshing and cleaning efficiencies were low. These values make them unsuitable for handling the millet crop without incorporating the modifications.

The IRRI axial flow thresher with cleaning unit was reported to have good performance on rice crop and therefore modifications were carried out to make it suitable for sorghum, millets, chickpea and pigeon pea grown under semi-arid condition by the farmers. The modifications were carried out to make it

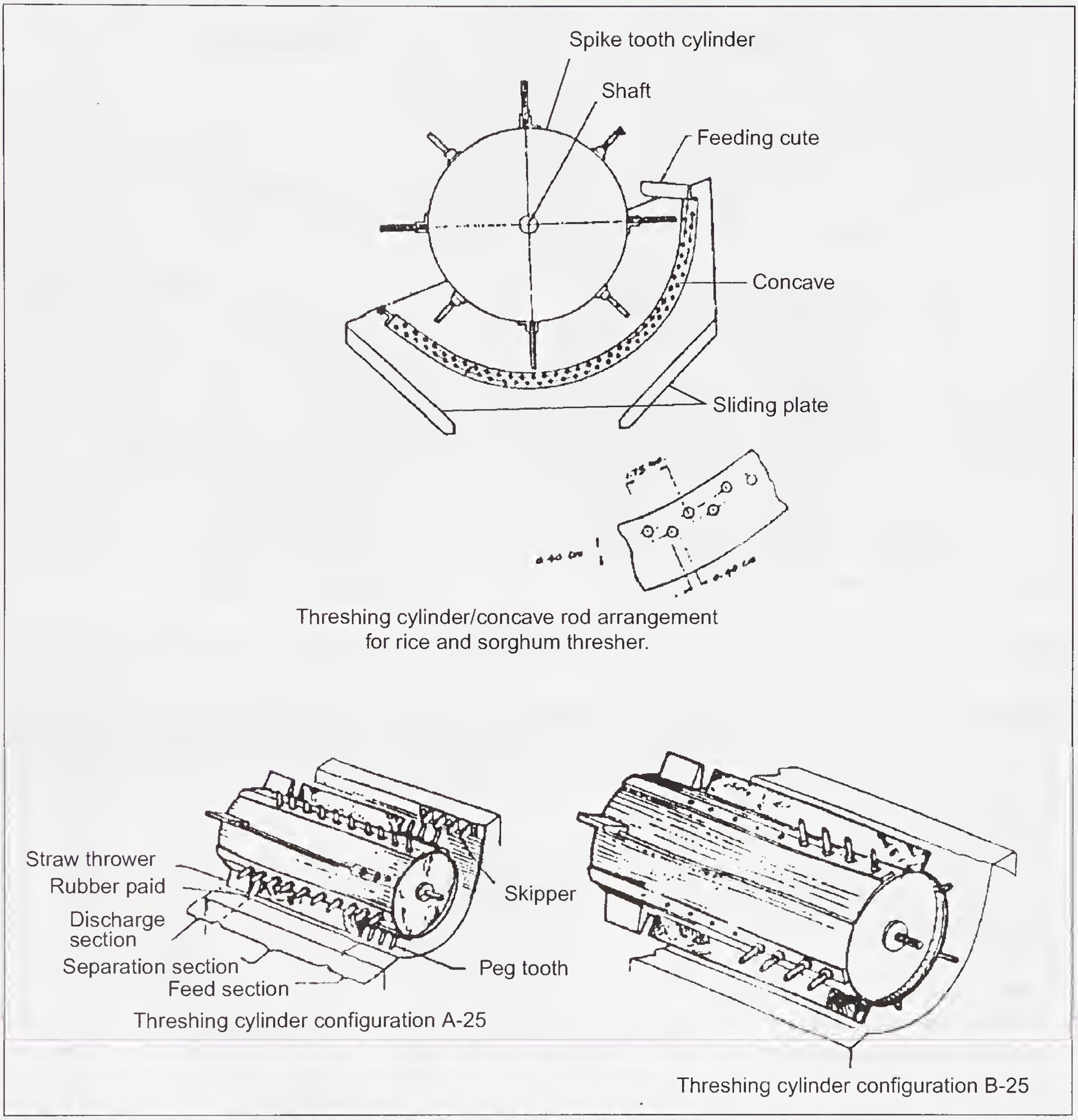

Fig. 8.4. Modified cylinder and concave for threshing of coarse cereals.

multicrop type thresher and these included:

1. Changing of cylinder speed,
2. Change in cylinder configuration,
3. Changes in the concave grate; making partially blanked,
4. Increasing the blower speed to improve cleaning efficiency, and
5. Change of cleaning sieves to suit the size of crop seed.

The changes made on cylinder were covering the pegs with flat belt flats for 1/3 of cylinder length. These are shown in Fig.8.4. The changes in concave grate were to reduce the size of openings by increasing more rods.

The portion of concave was blanked to prevent unthreshed grain falling on the cleaning sieves. The blower speed was increased to clean the grain and sieves were changed to suit different crops (Table 8.2).

The modified thresher was evaluated for its performance on the main crops, viz. paddy, sorghum, millet, pigeon pea and chickpea. The performance is given in Table 8.3 and 8.4.

Table 8.2. Sieve size used for cleaning different crops on modified thresher

Crop	Sieve I hole size, mm	Sieve II hole size, mm
paddy	8	6
sorghum	6	4
millet	6	2
pigeon pea	6	4
chickpea	6	4

Table 8.3. Optimum operating conditions for threshing crops with modified IRRI axial flow thresher (1987)

Crop	Moisture content	Threshing cylinder configuration	Concave configuration	Cylinder speed rpm	Concave clearance mm	Fan speed rpm	Sieve size I	Sieve size II	Speed of sieves
paddy IR-8	13-20	Pegs	m.s. rods welded	705-780	12	750	8	6	340
sorghum (CSH-6)	10-12	concave flaps (first 1/3+pegs)	modified (wire mesh in first 2/3)	780-860	6	800	6	4	340
millet (BJ-104)	10-12	canvas flaps (first 1/3+ pegs)	m.s. rods welded modified (wire mesh in first 2/3)	780-860	6	800	6	2	360
pigeon pea (ICP-2)	9-12	Pegs	M.S. nods welded modified (wire mesh in first 2/3)	630	8	900	6	4	400
chick pea local	9-11	canvas flaps with extra thick pegs for straw chopping	modified complete wire mesh in concave	780-940	6	800	6	4	340

Table 8.4. Results of modified IRRI axial flow thresher on threshing of crops

Crop	Moisture content (%)	Threshing efficiency (%)	Cleaning efficiency (%)	Blown grain (%)	Grain output (kg/h)
paddy IR-8	13-20	99	98	2	1,000
sorghum (CHS-6)	13	90	92	5	740
sorghum (CHS-8)	9.6	95	90	4	700
millet BJ-104	12.0	80	86	5	400
pigeon pea ICP-2	13.0	98	79	4	300
chick pea local	9.0	98	86	5	400

Thus, it was reported that with modification it was possible to thresh the sorghum crop but cleaning was not effective. In millet the threshing and cleaning efficiencies were on the low side.

Sorghum threshing with spike tooth thresher

At CIAE, Bhopal, wheat thresher of spike tooth type cylinder with slight modification in speed and change of sieve sizes were supplied to the farmers for threshing of sorghum in Maharashtra state. A thresher manufacturer in Nagpur, India, was exclusively making threshers of spike tooth type for threshing of sorghum and millet for those regions. The CIAE multicrop thresher (Fig. 8.5) was evaluated for threshing of sorghum. It was ensured to find the best operating conditions

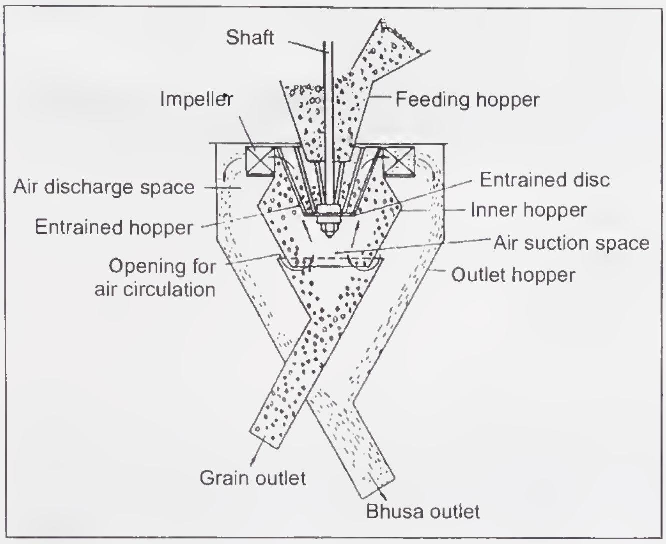

Fig 8.5. Working principle of centrifugal winnower.

can be increased in steps of 0.5 degrees. These changes made suitable for the threshing of crops.

The sieve slope changed by changing the hanger length on the thresher in horizontal position as given in Table 8.6. Thus thresher for sorghum gives the following performance: Sorghum variety, (CSH 9); Grain moisture, 7.6%; ear moisture level, 9.2%; straw grain ratio, 0.33; cylinder speed, 11 m/sec; feed rate, 725 kg/h; broken grain, 0.35%; blown grain, 0.14%; spilled grain, 0.07%; threshing efficiency, 98.9%; cleaning efficiency, 96.93%; output of grain, 540-kg/h; and energy consumption, 3 kWh.

Table 8.5. Recommended concave gap between bars, concave clearance at rear end, sieve size, sieve slope, stroke length for CIAE multicrop thresher

Crop	Concave with gap in bars in mm	Concave clearance at rear mm	Sieve hole size top in mm	Sieve slope angle degrees min and max values		Stroke length
Wheat	7	10	5	1	2.5	24-28
Sorghum	7 or 9	10	5	1.5	2.5	26-30
Soybean	7	15	9	3	4	26-30
Pigeon pea	7 or 9	10	9	2	2.5	24-28
Linseed	9	10	5	1.5	2.5	24-28
Sunflower	9 or 25	20	9	2	2.5	26-30
Maize	25	20	11	2	3.5	26-30
Paddy	9	20	9	1.5	3.0	24-28
Mustard	7	10	3	1.5	2.0	24-28

for the optimum performance of the thresher. For threshing sorghum the harvested ears are used and the threshing cylinder of spike tooth type was used as in case of wheat. The speed of operation was set for the crop as determined from field trials. The concave with 7mm gap between the bars was installed. To prevent partially threshed grain with glumes falling from concave, it was blanked in the feed inlet area of concave. Thus the completely threshed sorghum falls through the concave on the cleaning shoe for aspiratory and mechanical cleaning. The sieve sizes were changed for the sorghum. To prevent sieve overflow the slope of the sieve was made adjustable and the slope

However, it was concluded that further cleaning is required in sorghum before it is

Table 8.6. CIAE thresher setting for sieve slope with rear hanger length in horizontal position of thresher for cleaning of crops

Sieve slope in degrees	Rear hanger length in mm
0	145
0.75	155
1.0	162
1.5	168
2.0	175
3.75	195
4.5	205
6	225

accepted in the market. Thus, it was noted that a high capacity winnower was developed for sorghum.

Centrifugal winnower for threshed sorghum grain

Pachgare *et al.* (1995) reported the development of high capacity centrifugal winnower for sorghum (Fig. 8.5, 8.6 and 8.7) for use in the Akola region. The machine consists of a centrifugal type impeller at the centre of which is fitted hopper shaped container with open sides. The mixture of sorghum and *bhusa* is fed from the top in the centre of impeller type blower. The unit is powered by 3 hp size

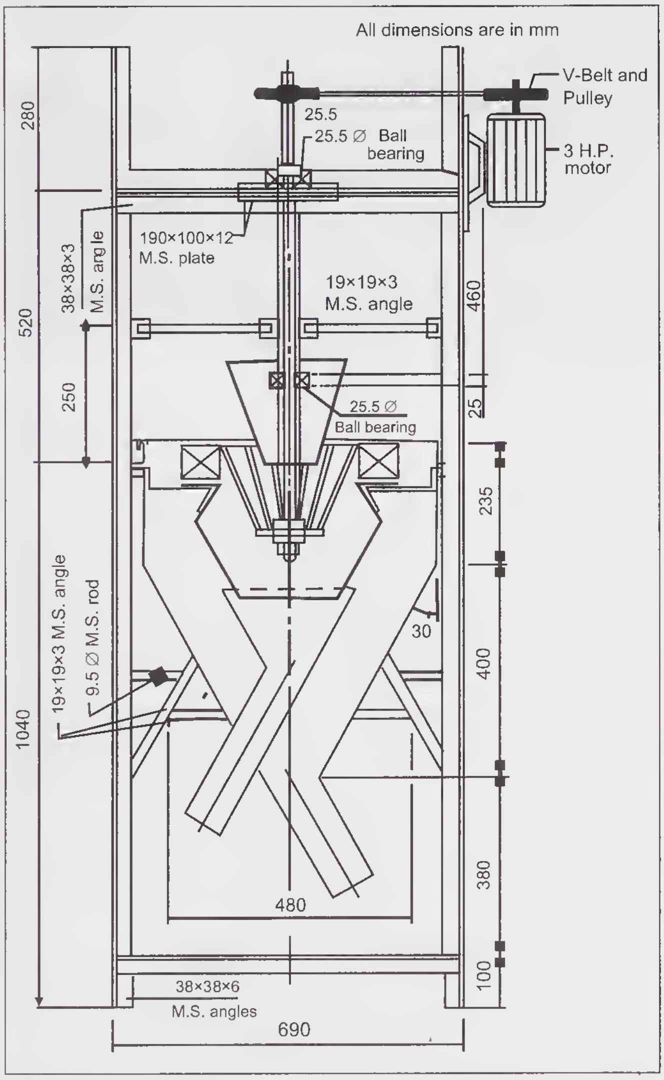

Fig. 8.6. Schematic diagram of centrifugal winnower for sorghum.

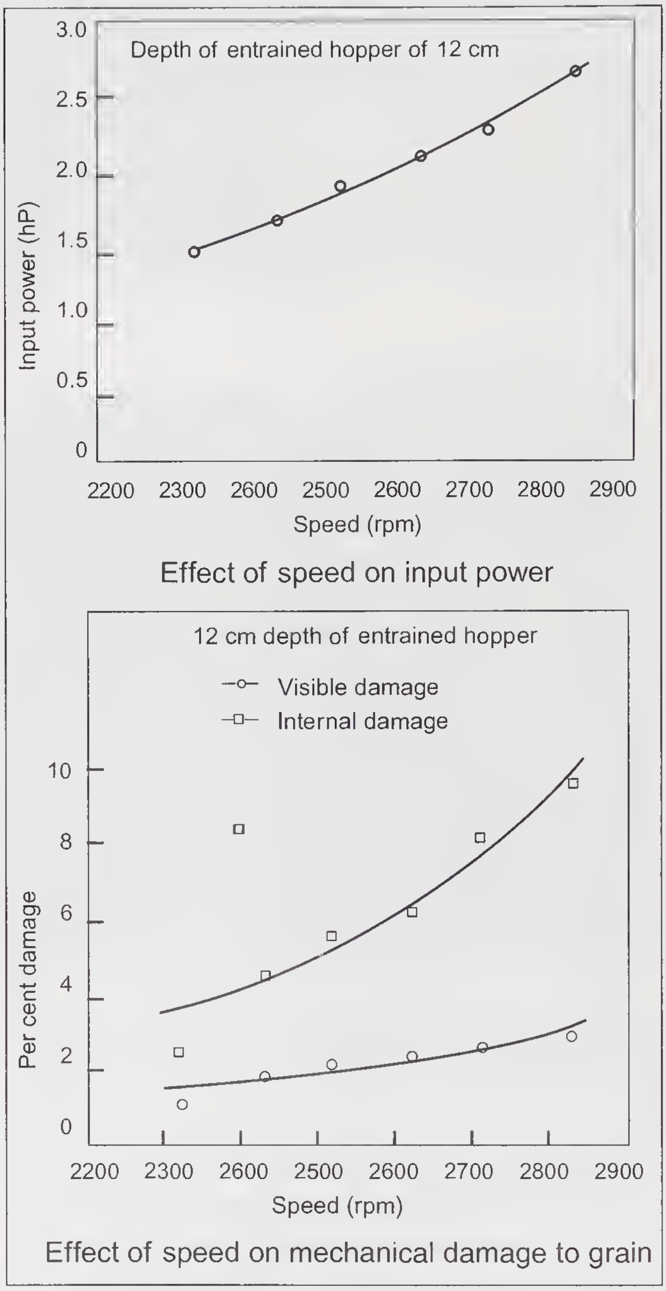

Fig. 8.7. Performance data for sorghum winnower.

electric motor. Due to rotary motion the mass of sorghum and *bhusa* / chaff is thrown out of the rotating chamber and due to air flow by the impeller the chaff is sucked up and thrown out in the outer cyclonic chamber. The grain is thrown out and after striking the inner conical shaped chamber falls due to gravity into the grain outlet chute. The outer chamber helps in collection of the complete chaff and husk.

The unit operates at a speed of 2,600 rpm. The depth at which material is fed into the

inlet chamber of the impeller is 12 cm deep. The capacity of winnower was reported as 900 kg/h. It has a cleaning efficiency of 97.67%. The amount of *bhusa* in the material used for testing was 20 %. The separation efficiency was reported as 88.6%. The unit is recommended, as it is a compact machine, which occupies less space and easy to operate.

Threshing of millets

The coarse cereals include crops like sorghum, pearl millet and millets. It was noticed that the area under coarse cereals is declining in the country at the rate of 1.69% per annum from 1975 to 1999-2000. The production levels have increased from 15.38 million tonnes in 1950-51 to 30.48 million tonnes in 1999-2000. The average yield levels of millets under rain-fed conditions are about 1,034 kg/ha. The yields are low because the crops are raised under arid and semiarid areas of the country. Any change in rainfall pattern at proper time can give a benefit to the farmer. The crops are grown as grains and fodder crops to sustain human and animal population. The farmers in these areas are economically weak and therefore mechanization is going on at a very slow pace. The millets are harvested as ear-heads from the plants. The plants are also harvested by the farmers as it is used as animal fodder. Therefore threshing of ear-heads of millets and pearl millet is very easy to thresher with the spike tooth type threshers.

The spike tooth type thresher developed for wheat can be utilized for threshing of pearl millet and millets. The threshing drum speed is set at 9-10m/sec. The top sieve in the cleaning shoe is to be about 2.0 mm diameter hole. The concave grate at the feeding zone is to be blanked so that the ears are threshed fully before passing through the grate. The blower air velocity and volume are changed to reduce blown grain losses. The performance of thresher has been reported under CIAE multicrop thresher.

The coarse cereals are grown by the small farmers of arid and semi arid regions. They are economically very weak. At the yield levels of 1,034 kg/h it is not possible for them to invest in the purchase of the thresher. However the simple, low cost drummy type thresher developed during 1963-65 can meet their crop threshing requirements.

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9 Threshing of Pulse Crops

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Soybean

Soybean (*glycine max*) is a pulse crop with potential to meet the protein and oil requirements of people in Asia where it is grown widely. The cultivation of soybean dates back to 1000AD. It was introduced from China in Asian countries. The cultivation picked up in India from 1970 due to introduction of soybean from USA. The state of Madhya Pradesh, Uttar Pradesh and Rajasthan adopted the cultivation of soybean at their respective state agricultural universities farms from this time, because of their linkages with universities in USA. The crop in Madhya Pradesh was grown under rainfed farming conditions and being short duration type it resulted in conversion of mono- cropped area under double cropping. With the demand for vegetable oil increasing in India due to increase in population and the high price of soy meal in the international market, the farmers and processors showed interest in the crop as there was the market for selling oil and oil cake. Therefore the farmers picked up cultivation of the crop, as it was suitable to agro- climatic conditions.

Utilization of soybean: The farmers in the state of Madhya Pradesh grow soybean during monsoon season and yield level of 1,200 kg/ha during 2001 have been achieved. The crop area increased to 6 million ha million during 2000. The 70 per cent of soybean produced in India is raised in state of Madhya Pradesh. The 75 % of soybean produced is used for the extraction of oil, 10 % is used for seed purpose and rest is used as food or feed. The various products of soybean have been developed, but the most important are soy oil, texturized soy protein, soy cottage cheese and snacks. A little quantity

of soymilk is also produced. It is to be further commercialized to increase its use among the people for meeting the protein requirements.

Economic constraints: The farmers raising soybean nowadays find the cost of cultivation increasing due to increase in use of farm workers. The major cost factor is the cost of manual labour. Singh (1993) reported that during 1984 the cost of labour was only ₹ 240 per ha. The cost has increased to ₹ 2200/ by 1996 and is growing every year. The crop is highly susceptible to shattering losses; it gets spoiled due to occasional rains during harvesting period. It is damaged due to rough handling during the harvesting and threshing operations. The damaged grain loses its value as the seed and creates storage problems because of accelerated attack by the microbes. Soybeans are very delicate and therefore require greater attention as threshing operation causes damage due to impact action of cylinder. The harvesting and threshing is to be done at the proper moisture level to avoid losses and maintain the quality of seed. Therefore the soybean farmers have to mechanize the crop production operations in particular the harvesting and threshing to reduce the cost of production and field losses.

The mechanization of agriculture was paid attention, as farmers started growing two crops with the introduction of soybean crop. Soybean- wheat, soybean –bengal gram, soybean-pigeon pea and wheat, crop rotations are followed from 1980 in state of Madhya Pradesh. Thus the production of soybean was linked with the farmers to adopt two crop production farming system. At this time, the farmers had a wheat thresher for threshing of wheat and it was to be modified for threshing of soybean to make it useful.

In the state of Rajasthan pulses (leguminous crops) are grown during *rabi* (winter) season (due to lack of irrigation facilities) on the conserved rainwater. Hence the development of a simple rasp bar type-threshing unit with provision for changing the cylinder speed and the concave clearances to determine the proper operating conditions for threshing was taken up.

Development work on soybean thresher

The thresher development for soybean was started at College of Technology and Agricultural Engineering, Udaipur, India. The College of Technology, GBPUAT, Pantnagar, in Uttar Pradesh and College of Agricultural Engineering, JNKVV, Jabalpur in Madhya Pradesh took up the development of soybean threshers to meet the local requirements during 1971-75. The thresher for soybean at Udaipur was an experimental unit operated by a 2 hp electric motor. It consisted of a rasp bar type-threshing cylinder fitted with a concave grate with adjustment for clearance. The clearances of 4,8,12 mm were set during trials for having a minimum of the seed damage.

At low concave clearance of 4 mm the threshing efficiency was high but the seed damage was high. For seed purpose the recommended speed was 413.5 mpm with concave clearance of 12.0 mm. This was for soybean variety Bragg for sun-dried crop having a moisture level of 6.1 per cent. The grain output was 64 kg/h with feed rate of 200kg/h (Fig. 9.1).

The maximum grain output of thresher was 85 kg/h. The weight of thresher was 40 kg. The unit was provided with a blower to remove the chaff and other plant material after threshing. The crop feeding was done manually.

The experimental thresher (Fig. 9.2) was operated by the variable speed drive to change the speed of cylinder as required and the concave grate was designed so that the concave clearance can be changed to minimize grain damage. The results of threshing studies conducted on soybean and other crops are given in Table 9.1.

The study covered threshing of sunflower crop variety (EC 68414) harvested and dried with moisture level of 4 %. The tests were

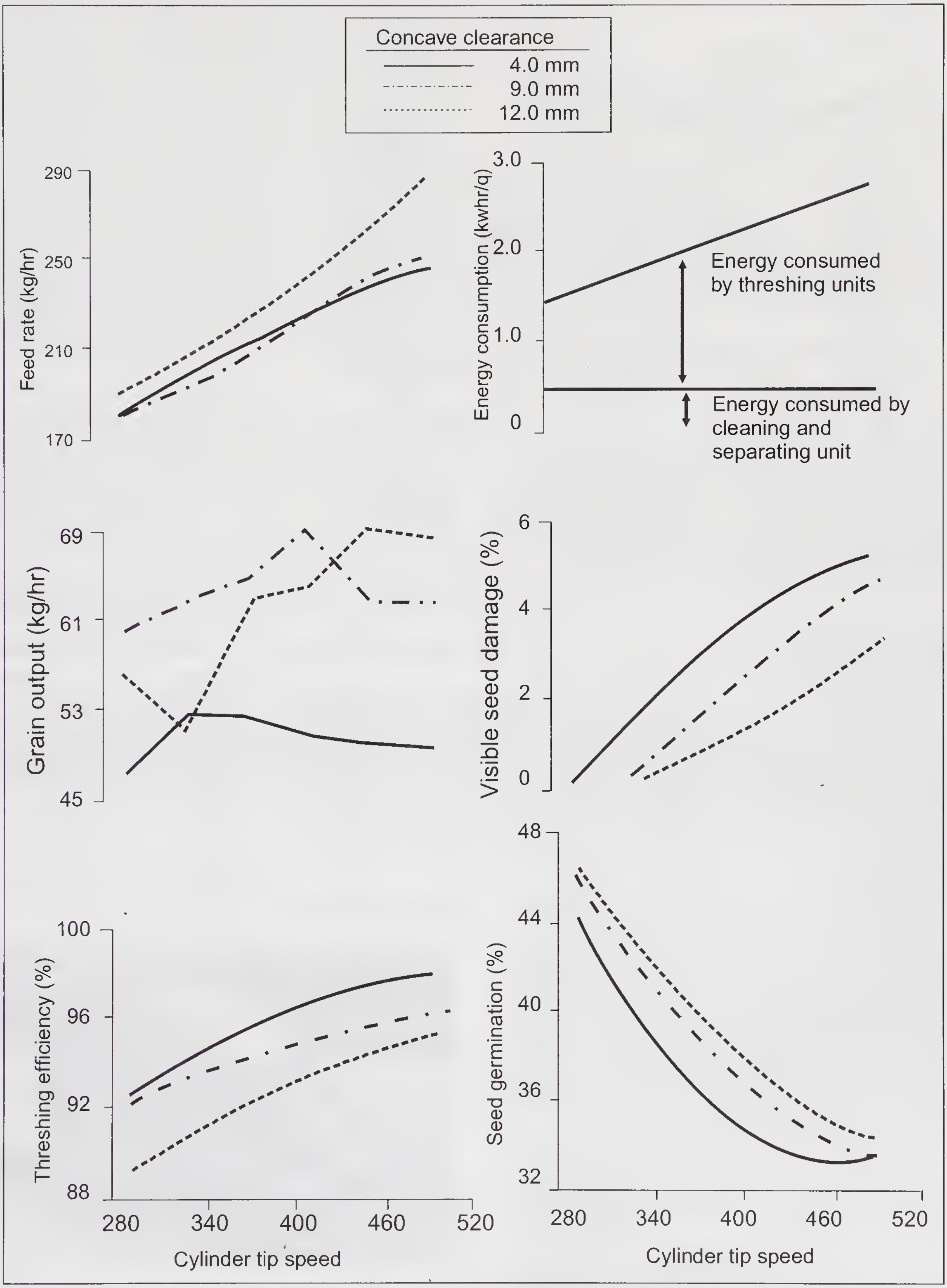


Fig. 9.1. Effect of cylinder speed and concave clearance on various threshing parameters of soybean Bragg variety (Sharma and Devnani, 1979).

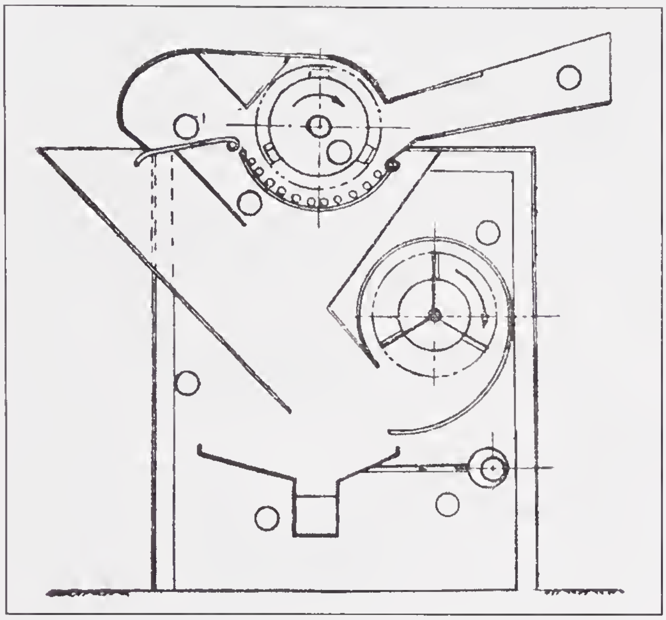


Fig. 9.2. Soybean thresher developed in Udaipur. 1. Concave extension 2. Concave 3. Frame 4. Delivery spout 5. Cylinder 6. Feeding tray 7. Blower 8. Eccentric drive.

cowpea the threshing speed was 496 mpm with concave clearance of 8 mm. The feed rate of crop was 160 kg/h and the grain output was 31.6 kg/h. The energy consumption was 3.25 kWh per quintal of grain. These studies indicated that for threshing various crop the cylinder speed and concave clearance are different. The increase of speed increased the output of thresher, increased the seed damage and reduced the germination percentage. It was concluded that a simple threshing unit could be used to thresh the oilseed and pulse crops.

High capacity soybean thresher (Fig. 9.3)

Soybean thresher developed at Pantnagar was tractor or 15 hp electric motor operated flow through type. The thresher consisted of crop feeding system, threshing unit with concave grate, and cleaning and separation unit. The cylinder was fitted with rasp bars.

Table 9.1. Summarized results of threshing studies on crops studied and reported by Sharma and Devnani (1979 and 1980)

Crop	Feed rate kg/h	Cylinder speed mpm	Concave clearance mm	Threshing efficiency Per cent	Grain output kg/h	Energy consumption KWh/100kg
Sunflower (EC 68414)	425.0	330	12	98.3	278.0	4.5
Mustard (Sufla)	62.5	413	4.0	97.1	31.6	5.5
Cowpea (Local)	160	496	8.0	95.6	31.6	3.25
Soybean (Bragg)	206	413.5	8.0	94.1	64.0	2.0

conducted with cylinder speed varying from 288.5 to 496 m/min and concave clearances of 4,8,12 mm. The study was for determining the safe operating speeds with seed damage within 2% for seed purpose and for grain purpose 5 per cent damage was considered at the acceptable levels.

For mustard the feed rate increased to 75 kg from a low of 60 kg/h when the speed of cylinder was increased. The minimum seed damage of less than 2 % was obtained with the thresher drum speed of 413 mpm and concave clearance of 4.0 mm. At this speed efficiency was 97.1 % and seed damage of 1.83%. For

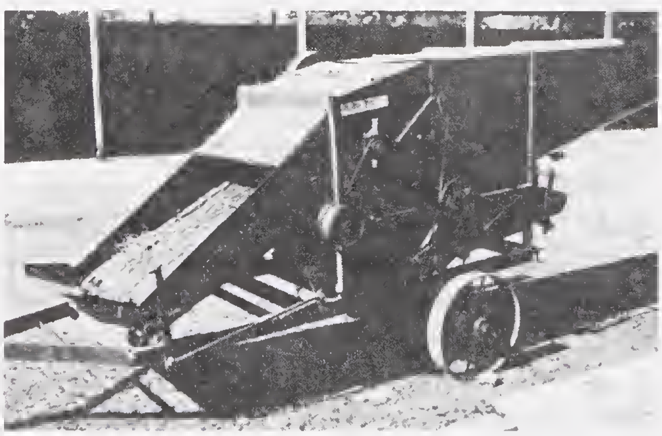


Fig. 9.3. Cross flow type soybean thresher developed at Pantnagar.

The straw walker and cleaning shoe with a grain elevator were provided to do the bagging of the grain. The unit was provided with variable speed drive pulley to vary the speed of the threshing cylinder. The unit was fitted with a clutch arrangement to disconnect the power to the threshing unit. The unit was able to thresh the crop at the rate of 700-900 kg. The weight of thresher was 800 kg. However the cost of Pantnagar thresher was prohibitive for the small farm holders.

The thresher developed at Jabalpur was the modified paddy power thresher, which was a 3 hp electric motor operated unit. The threshing cylinder was the wire loop tooth type. The teeth on the cylinder were reinforced for soybean and wheat. The complete crop was fed into the machine. Thus concave and cleaning units were modified to handle the material. The unit was reported to thresh the soybean crop with grain output of 300 kg/h.

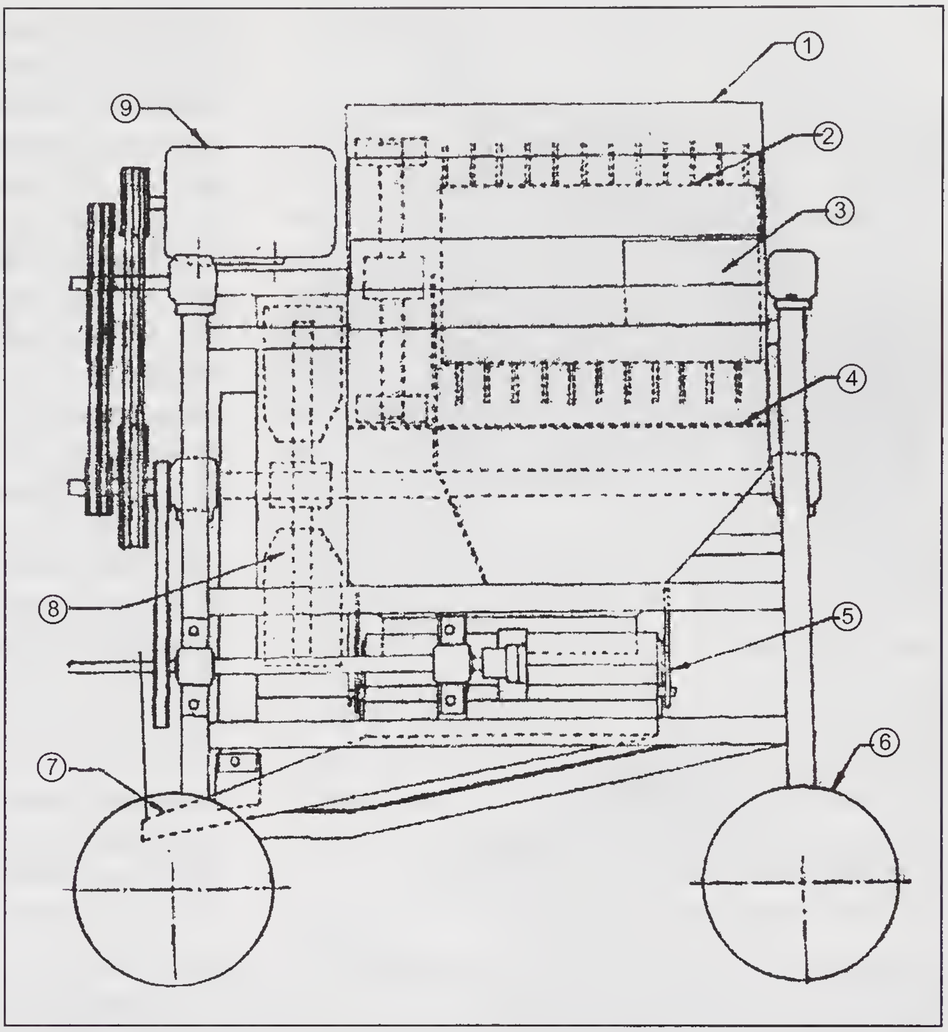


Fig. 9.4. CIAE multi crop thresher for soybean threshing (Axial Flow Type). 1, Top cover; 2, Cylinder; 3, Feed inlet; 4, Concave; 5, Sieve shaker; 6, Wheel; 7, Grain outlet; 8, Blower; 9, Motor.

Multi-crop thresher for soybean (Fig. 9.4)

The development of multicrop thresher was started during 1982-1984 at CIAE, Bhopal. The commercial wheat threshers were evaluated on soybean crop. It was reported that only spike tooth type thresher having an independent drive to cylinder and blower could be used to thresh soybean and other crops.

For threshing of rice crop only axial flow thresher was required to meet the threshing of crop at high moisture level. Therefore multi-crop thresher was designed for threshing of crops like rice, wheat, maize, sorghum, gram and soybean by feeding the whole crop, except in maize, sorghum and sunflower where the cobs or ear heads were fed. Thus design was to meet the need of farmers:-

- It should be operated by an electric motor of 5 hp.
- It should make a fine *bhusa* in case of wheat.
- It should not damage the rice straw.
- The design should be simple, safe to be produced by local industry.

- It should meet the Indian standards for safety.

Description of machine: It consists of feeding tray, spike tooth cylinder straw thrower, blower and cleaning sieves. The cylinder is fitted with rectangular shaped flats as a beater welded on eight bars on the cylinder in staggered fashion. On the rear end of the threshing cylinder impeller blower blades for throwing long straw in paddy is provided. While threshing other crops the straw thrower is partitioned off from the threshing unit. The bruised straw and grain after getting threshed fall on the cleaning shoe sieve. The concave provided is made from square bars with fixed openings and to take care of different crops three concave grates are provided. The semi- hexagonal top cover with spiral louvers is provided for threshing of paddy crop only. In other crops the circular top cover is placed along with a semi circular disc to prevent material entering in the straw throwing impeller.

The crops like wheat, gram, sorghum, soybean etc are to be fed into the threshing cylinder through the inlet, here the crop is beaten by the cylinder and the threshed grain along with straw and chaff falls on the top sieve of the cleaning shoe. The cleaning shoe further cleans the grain by aspiratory blower, which sucks out the light material and allows the threshed grain to be cleaned by the sieves. The unthreshed tailings fall at the outer end of the top sieve along with heavier straw. The three concaves with gaps between bars of 7 mm, 9 mm and 25 mm are provided to take care of most of the crops. The 25 mm gap concave is used for threshing of sunflower and maize crop. The 9 mm concave is used for threshing of Bengal gram, soybean, and paddy. During threshing of Bengal gram and other pod type pulses the feed inlet portion of the concave is blanked. The wheat crop is threshed with 7mm concave grate. An aspirator blower is mounted behind the cylinder with two suction openings, one at the separating chamber and the other at the grain outlet. The blower sucks out the lighter material and blows out of the

Table 9.2. Summary of threshing test results on CIAE multicrop thresher

Item	Crops							
	Gram	Wheat	Soybean	Sorghum	Maize	Paddy	Pigeon pea	Safflower
Variety	Radhe	HD 4530	JS7244	CSH 9	Ganga 5	Pusa 21	JA 3	JSF 1
Straw grain ratio	1.04	1.28	1.8	0.33	0.15	1.5	-	2.6
Straw moisture %	8.8	5.2	9.6	9.2	14.8	12.2	9.5	6.3
Grain MC	7.8	8.3	8.9	7.6	11.2	14.5	7.5	6.1
Cylinder speed	11.0	19.4	7.8	10.5	8.4	13.6	9.2	9.2
Feed rate kg/h	714	645	560	725	1878	995	-	550
Energy consumption, kWh	2.4	3.4	2.8	3.0	3.3	2.6	2.04	2.1
Broken grain %	0.52	0.35	2.2	0.35	1.0	0.01	0.21	1.1
Blown grain %	Nil	0.03	Nil	0.14	Nil	0.153	0.16	0.6
Spilled grain %	0.56	0.08	0.61	0.07	1.1	0.8	0.11	0.8
Threshing efficiency %	99.2	99.8	98.8	98.9	99.9	99.1	99.5	99.5
Cleaning efficiency	94.6	99.01	93.0	96.93	99.3	94.5	95.1	98.0
Grain output, kg/h	348	276	200	540	1635	392	98	150

machine from the blower outlet. The cleaning sieves are hinged at the bottom of a cylinder concave on adjustable hangers. The separation of grain from straw mixture takes place due to oscillating motion of shaker assembly and the grain fall through the top sieve on the second sieve and comes out at the main grain outlet.

The cylinder and shaker get power from the blower shaft through v- belt and pulley drive. The concave clearance, sieve clearance, screen slope, cylinder speed are adjustable to meet the requirements of the various crops.

The thresher was subjected to various tests as per the IS: 6284 test code at various speeds and feed rates for threshing of wheat, gram, soybean, sorghum, maize and rice crops. The performance data on the threshing of above crops are given in the Table 9.2. The extensive trials were performed at various net-work centres of agricultural universities in India. The soybean was threshed with a spike tooth type thresher at cylinder speed of 7.8 m/s, concave grate gap of 9 mm and with 5 hp power unit the output of 200 kg/h was obtained for JS 7244 variety. The economic analysis on the basis of costs and wages rates during 2001 indicated that the payback period for thresher was threshing of 145 tonnes of grain. This is equal to use of thresher for a period of at least 300-350 h /year.

Multi-crop threshers developed in Thailand: The thresher for black gram of multicrop type was developed and commercialized in Thailand. The details of thresher are shown in the Fig.9.5.The whole crop is fed in the thresher. It is fitted with axial flow threshing cylinder (Fig. 9.6) with a concave. The entire plant material is rotated inside the threshing unit to separate the grain from the pods. In this process the plant mass is broken up and is moved axially along the length of threshing drum. The grain is sifted through the mass of straw and falls on to the cleaning unit through the concave grate. The entire cylinder is covered with the concave cage. The length of concave cage is 915 mm

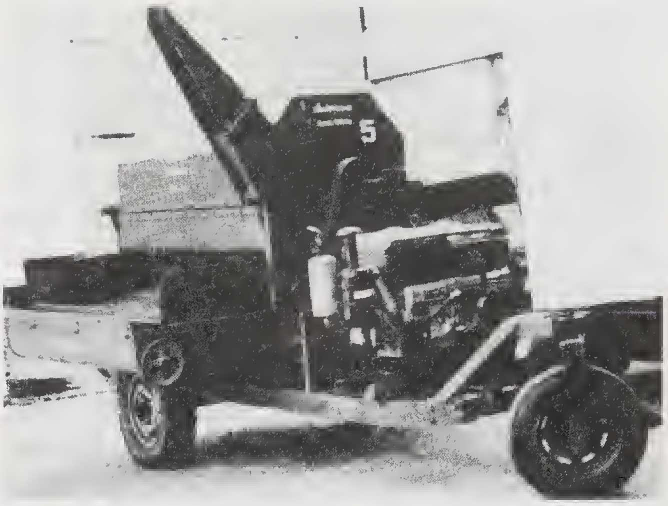


Fig. 9.5. Multi-crop thresher manufactured and marketed in Thailand for threshing soybean, black gram and sorghum.

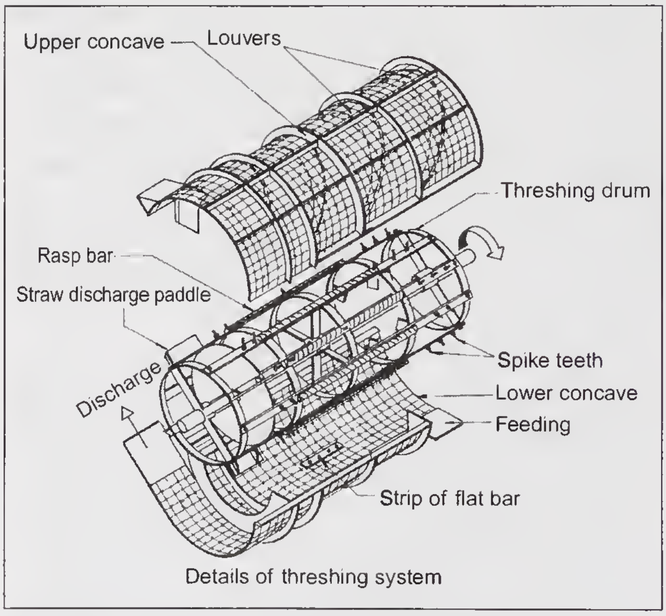


Fig. 9.6. Details of axial flow threshing unit developed at Thailand.

length. The cleaning unit is fitted with two sieves and blower. The light material is blown out and the clean grain is collected. An engine of 10-12 hp diesel engine operated the thresher. It is mounted on wheels for portability. The output of thresher reported was for soybean 400-600 at threshing speed of 400-550 rpm, for sorghum output was 1200-1550 at 500-600 rpm and 400-600 kg/h for black gram at 350-450 rpm.

Thresher for Bengal gram

India is the largest producer and consumer of pulses in the world as these are the major source of protein for the large section of vegetarian population. Its contribution in the world production of pulses is 23 %. Pulse crops also improve the soil nutrients by biological fixation of nitrogen. A variety of pulses are grown in India, the popular pulses being Bengal gram, green gram, red gram, arhar (*tuar*), lentil (*masoor*), black gram (*urad*), pigeon pea, peas, cowpea, beans, rice bean, and moth beans etc. The production of pulses has not increased as result of which the per capita availability per day reduced from 60.7 g from 1950 to 37 g/day during 1999. The total production in 1999-2000 was 13.35 million tonnes from 21.19 million hectares of crop area. The production has increased to 14.76 million tonnes during 2007-2008. The major states growing pulses are Madhya Pradesh, Maharashtra, Uttar Pradesh, Rajasthan, Karnataka, Andhra Pradesh, Bihar, and Tamil Nadu. The pulses are grown in dry land regions as the area under irrigated crop is only 12%. The average estimated yield is about 635 kg/ha.

The major constraints in pulses are the biotic stresses. Wilt, yellow mosaic, blight and powdery mildew are the diseases, which cause considerable loss. The gram pod borer, pod fly in pigeon pea, white fly, and jassids in green gram (mung bean) and aphids in lentil, stem fly in dry pea are the insects cause losses in production. Pulses are grown as mixed or as inter crop by the farmers. However yield levels of 1.5-2.0 tonnes have been reported in pulse crops under favourable crop producing conditions.

Bengal gram: Bengal gram is the major pulse grown and consumed by the people in India. The total area under this crop during 1999-2000 was 6.31 million hectares with production of 5.08 million tonnes. The states of Madhya Pradesh, Uttar Pradesh, Rajasthan and Maharashtra are the major producer of gram. The yield levels of gram are low as it is grown under rain-fed conditions. The recent trend of application of chemical fertilizers and irrigating it has increased the yield levels.

Bengal gram is a bushy type plant and has pods spread all over the branches of plant. It is harvested manually with sickles close to the ground level. The pulses are mostly seasonal such as rainy season (*kharif*) and winter (*rabi*) crops. The growing season is 90-100 days in duration. The pulses grains are mostly produced in pods. The pods may have seeds varying from one to two and the number can be up to 20. The pods are loosely attached or strongly attached depending upon the crop. The plants are mostly branching type and spread along the ground. The branching

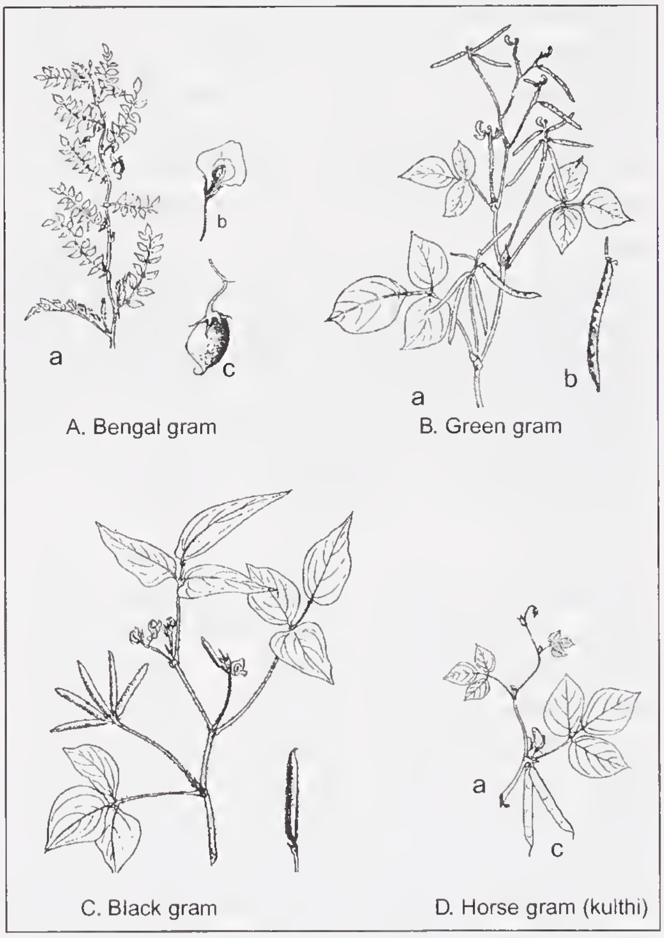


Fig. 9.7. An apical portion of branch of (a), Bengal gram (chickpea) plant and the pod; (b), Mungbean or green gram and pod; (c), black gram and pod, and (d), horse gram or *kulthi*.

pattern of gram is typical; two primary branches develop at the ground level, which in turn along with the main shoot branch further. The main stem is rounded and thin and covered with hairs. The leaves are of small size 4x6 mm. The Bengal gram is known as chickpea is plant of spreading type and pods are found all along the branches of the plants. It is harvested when grains are green and tender and used as vegetable. When the crop matures the grain can be dark brown, yellow and yellowish black. The variety having white grain is known as *Kabuli* gram or Chickpea (Fig.9.7).

The threshing of Bengal gram was carried out with the existing wheat threshers at CIAE, Bhopal. It was reported that for proper threshing the cylinder speed is to be reduced to avoid seed damage, and the cleaning efficiency was low. However it was noted that the spike tooth cylinder was able to thresh the crop properly.

Therefore the CIAE multi-crop thresher was evaluated by making adjustments on the threshing cylinder speed, blower speed, cleaning sieve size and slopes. It was reported to have given the desired performance.

Threshing of gram: The crop is harvested with reaper or manually and threshed. The harvesting of gram is usually before the wheat crop. The crop is fed into the threshing unit of spike tooth cylinder along with stalks. By fitting the semi circular disc and semicircular top cover makes CIAE multicrop thresher similar to wheat thresher. But to take care of Bengal gram seeds the concave with gap between concave bars of 7-mm is selected. The top screen with hole size of 9 mm is placed in the cleaning shoe. The blower shaft pulley of 150 mm and corresponding cylinder shaft pulley of 250 mm is installed. The sieve slope is set according to crop condition and slope of sieve initially is set at 2 degrees, it is increased in steps of 0.5 degrees till the desired cleaning level is obtained.

By setting cylinder speed of 11 m/sec and blower speed of 800 rpm, it was noted that with feed rate of 714 kg/h the output of Bengal gram variety 'Radhe' was 348 kg/h at 7.8% moisture level. The threshing efficiency was 99.2 %. The cleaning efficiency was 94.6 %. The broken grain during threshing was 0.52%. The blown grain was nil. The spilled grain over the sieve was 0.5 % (Table 9.2). The cleaning efficiency was low because the plant stems were thin and fibrous. Therefore they didn't break into small pieces to be blown away.

In case the air blast was increased it resulted in greater percentage of blown grain losses. Thus straw pieces come out with grain. When the sieve slope is not correct they clog the top sieve during continuous operation. In Bengal gram threshing the feed inlet portion of the concave is blanked with plain sheet to avoid detached pods to come out as unthreshed pods in the threshed grain.

Thus spike tooth type thresher was used for threshing of Bengal gram (chickpea) by making the simple changes in concave openings according to the size of seed and changing the cylinder speed. It was noted that the Bengal gram seed is hard and little damage was noticed during threshing at cylinder speed of 11 m/sec. The top sieve of the cleaning sieve is also to be adjusted to suit the size of seed. In Bengal gram the straw may not be bruised completely before it falls on the top sieve. Thus long stems of plant have tendency to block the sieve holes and this may result in sieve overflow losses. This problem can be solved easily by blanking the first 10 cm of the sieve thus the stems have time to fall on the sieve in horizontal position and are thus removed at the end of top sieve without choking. So gram can be threshed by spike tooth type thresher.

Green gram (Mungbean)

Green gram is another pulse, which is grown widely in India and consumed by the people on large scale. Green gram is mostly grown after the harvest of rice or paddy crop.

The field has enough conserved moisture for the green gram to establish itself and grow. It is a bushy plant and is of short duration type. The pods with seeds are slender and long. They are harvested manually or harvested as whole crop at the maturity manually. As the crop is grown on small plots in paddy fields the traditional methods of threshing are widely used. However with increasing demand for this pulse the production on commercial scale is carried out. CIAE multicrop thresher can be used to thresh this crop. The harvested crop is sun dried on the threshing floor before threshing. In case the threshing is to be done by feeding whole plant the unit is to be set as axial flow thresher. When pods and some plant material (after removal of bulk of material other than pods) are to be threshed the thresher is set for radial flow threshing such as wheat thresher.

Agricultural Engineering Division Department of Agriculture, Bangkok and the National Institute of Thailand reported the development of Mungbean thresher during 1987. The commercial units of thresher (Fig. 9.8) were produced in Thailand. In this thresher the entire plant mass is fed into the feed inlet of thresher. The principle used is the axial flow threshing, the feed inlet portion of the concave is blanked and the pods are carried over to the threshing zone where grains (kernels) are separated on the concave grate.

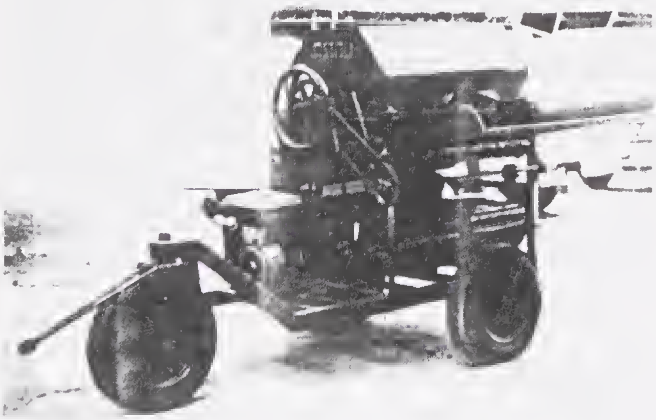


Fig. 9.8. Commercially available mungbean thresher in Thailand (*Source:* RNAM catalogue of Agricultural Machinery, 1991).

The details of threshing unit are shown in (Fig. 9.9). The weight of thresher was 400 kg. It is operated by 5 hp diesel engine. The recommended cylinder speed of operation was 500 rpm; the capacity of thresher was 500 kg/h with threshing efficiency of 95 % and cleaning efficiency of 99 %. Breakage of seed was less than 0.5% and losses within 0.5%.

Black gram

Black gram or *urad* is one of the important pulse crop in India. Black gram (*Vigna mungo* L.) is reported to be originated in India. Its references have been found in Vedic texts. India is the largest producer and consumer of black gram in the world. Black gram is a rich source of protein. It contains about 26% protein, which is almost three times that of cereals. Black gram supplies a major share of protein requirement of vegetarian population of the country. It is consumed in the form of split pulse as well as whole pulse, which is an essential supplement of cereal-based diet. The combination of (pulse-rice) is an important ingredient in the average Indian diet. The biological value is improved greatly, when wheat or rice is combined with black gram because of the complementary relationship of the essential amino acids such as arginine, leucine, lysine, isoleucine, valine, phenylalanine, etc.

It also plays an important role in sustaining soil fertility by improving soil physical properties and fixing atmospheric nitrogen. Being a drought resistant crop, it is suitable for dry land farming and predominantly used as an intercrop with other crops.

Black gram belongs to family Leguminoseae. The plant attains a height of 30 to 100 cm, with stem lightly ridged, and covered with brown hairs and branches from the base. The leaves are large, trifoliate and are also hairy, generally with a purplish tinge. The pods are long and cylindrical and about 4 to

6 centimeters in length. There are four to 10 seeds in a pod. The seeds are generally black or very dark brown.

In Andhra Pradesh 555 thousand hectares (18% of total area) of black gram was grown, which was the largest producer of black gram (390 thousand tonnes) of the total production, during 2000-2001 in India, followed by Maharashtra, 574 thousand hectares (19%) with production of 205 thousand tonnes. The area under black gram in Uttar Pradesh was 385 thousand hectares (13%) with production 163 thousand tonnes, whereas in Tamil Nadu, the area and production was 276 thousand hectares (9%) and 127 thousand tonnes (10%) respectively. Similarly, in Madhya Pradesh, the area under the crop was 420 thousand hectares (14%) with the production of 106 thousand tonnes (8%). These five states together contributed about 73% of total area and 76% of total production, under the black gram, during 2001. The black gram is grown in many Asian countries like Sri Lanka, Thailand, Pakistan, Philippines, and consumed by the people.

However, in productivity of black gram in India, Sikkim stood first with yield level of 737 kg/ha, followed by Andhra Pradesh (703 kg/ha), West Bengal (522 kg/ha.), Punjab (485 kg/ha.), Tamil Nadu (462 kg/ha) and Uttar Pradesh (423 kg/ha) during 2001.Because of low level of yields and production of black gram on farmers field being small the crop is threshed with traditional methods. Many farmers thresh the crop by passing it through the threshing unit and air winnowing or use of grain cleaner for cleaning of threshed material.

The thresher for black gram of multicrop type was developed and commercialized in Thailand. The details of thresher are shown in the Fig. 9.9.

The whole crop is fed in the thresher. It is fitted with axial flow threshing cylinder with a concave. The entire plant material is rotated inside the threshing unit to separate the grain from the pods. In this process the plant mass is broken up and is moved axially along the length of threshing drum. The grain is sifted through the mass of straw and falls on to the cleaning unit through the concave grate. The entire cylinder is covered with the concave cage. The length of concave cage is 915 mm. The cleaning unit is fitted with two sieves and blower. The light material is blown out and the clean grain is collected. An engine of 10-12 hp diesel engine operates the thresher. It is mounted on wheels so as make a portable unit. The output of thresher reported was about 650 to 750 kg/h.

The thresher is based on the axial flow principles of threshing. The threshing drum used is 915 mm long. It is divided in three sections. The first section is of 220 mm length covering the feed inlet or feeding zone. In this zone the crop is pulled inside the machine. The middle portion of 540 mm is the main threshing and separation zone. The last portion of 225 mm is the straw breaking and discharging zone as it is fitted with the pegs mounted on the drum for breaking the straw and paddles for throwing straw. The threshing cylinder is fitted with rasp bars in threshing zone and last portion is fitted with spikes on the drum to break up the straw. The concave is mostly made from 15mm square wire mesh. The bottom portion of concave in threshing zone is fitted with stripping bars. The upper portion of concave is also semicircular and is covered with wire mesh and last portion of concave is provided with concave with 18 mm openings to break up straw. The outer diameter of cylinder is 317.5 mm. The concave is of semi circular shape and inside diameter is 360 mm thus the clearance is about 20 mm. The crop threshed should be at moisture level of 9-12 % wet basis.

By changing the speed of threshing drum to 350–450 rpm the thresher was able to thresh the black gram crop. It was able to thresh the sorghum crop at the rate of 1,200–1,550 kg/h by keeping the drum speed of 500–600 rpm. The threshing efficiency for the crops was reported as 99 % and cleaning efficiency was

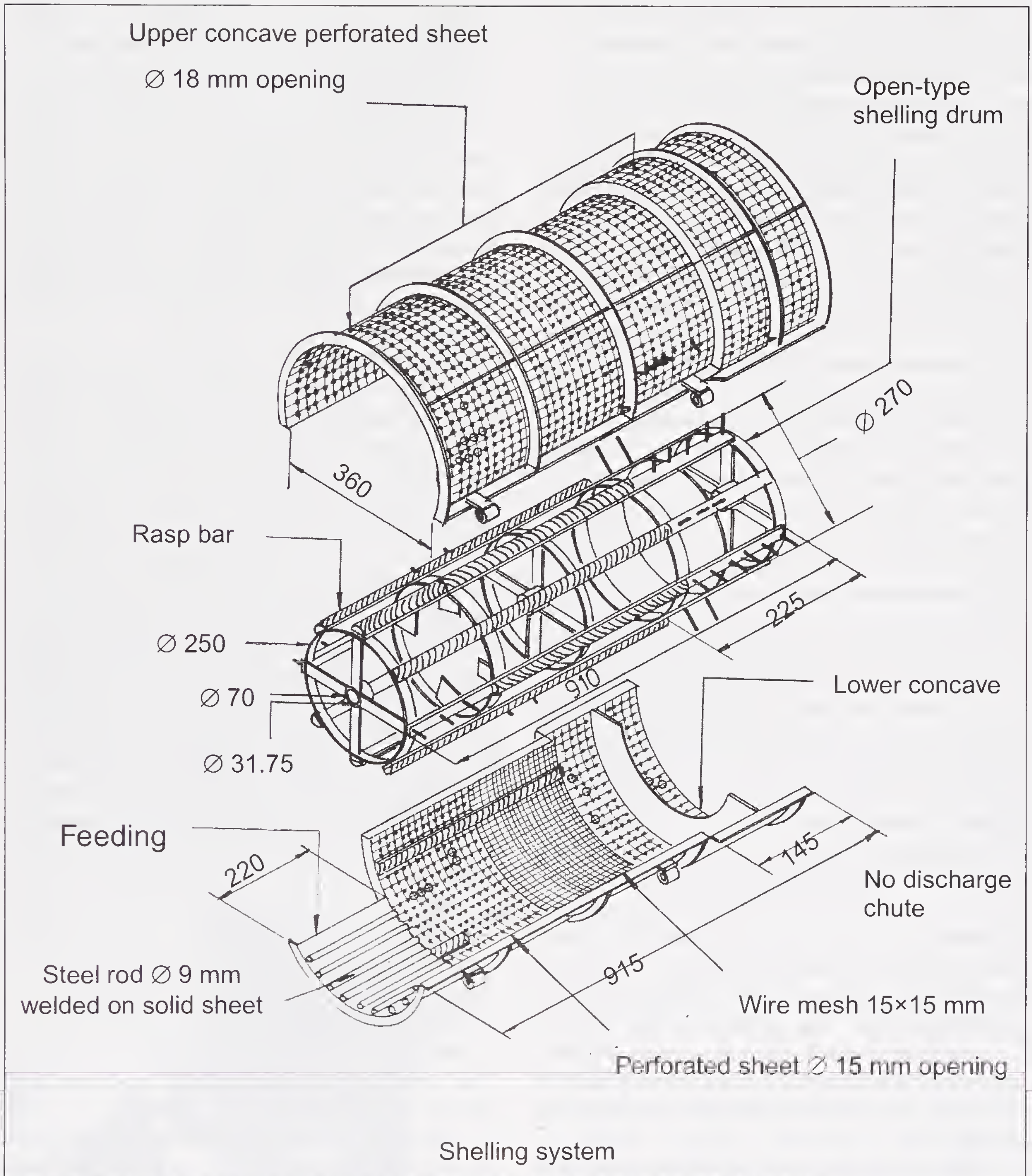


Fig. 9.9. Details of threshing unit developed for mung bean or green gram at Thailand.

over 99 %. The total losses were less than 1 %. The thresher is operated by 10–12 hp diesel engine. The fuel consumption was 1.2–1.5 litres/h. The cost of thresher reported was US$ 2000 during 1992.

Horsegram: The horse gram (*Kulthi*) pulse

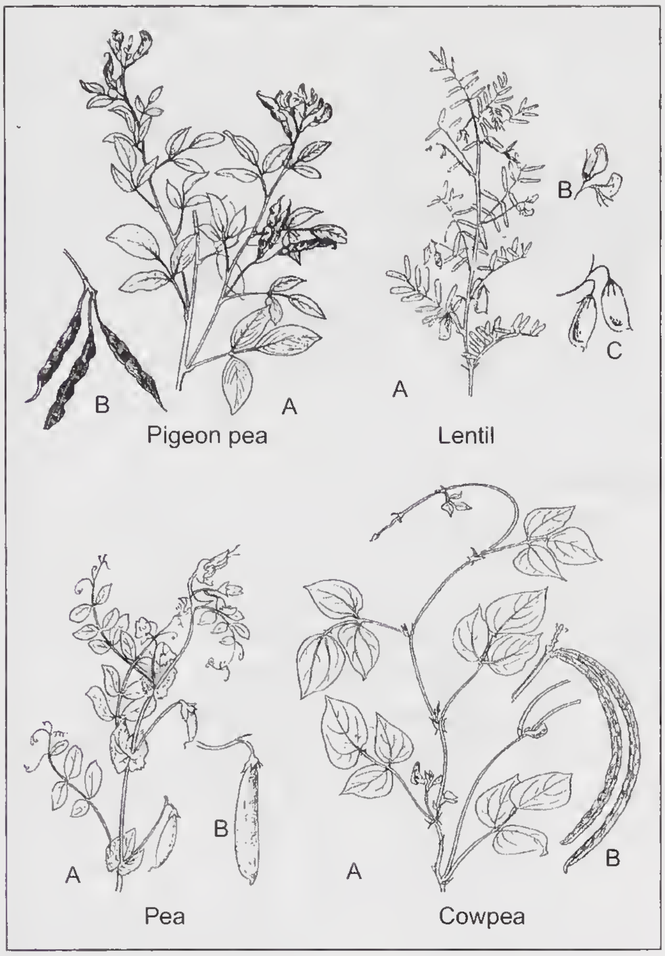


Fig. 9.10. An apical portion of branch of pigeon pea with pods, lentil and fruit, peas with pod, and cowpea portion of branch and fruit.

is grown in many states. It is known as *kulthi*. It is a pod fruit with number of seeds in a pod (Fig. 9.7). The local threshing methods are used but the threshers used for threshing of soybean, green gram and black gram can be used to thresh this crop.

Pigeon pea

The four pulses pigeon pea, pea, cowpea and lentil are grown in India and pigeon pea is most important as it is widely grown and consumed by the population. The peas and cowpea are raised and mostly consumed as vegetables. A portion of crop is allowed to mature and used as pulse (dry seeds) during the off-season. The lentil is mostly consumed as pulse with rice. The pigeon pea is a plant, which grows erect. It is also branching type and produces branch about 30-40 cm above ground. The height of plant is more than 100 cm. The stem is valuable for the farmers as it is used as firewood for cooking and other uses on the farmstead. The plant material of other three pulses is tender and it is used as animal feed. The Fig. 9.10 shows the apical portion of branches with fruits or pods

Production of pigeon pea: The production of pigeon pea in India is 90% of the total world production. The local name of pigeon pea is *tur or arhar.* The major production regions are Maharashtra (31.2 %), Uttar Pradesh (19.7%), Madhya Pradesh (12.9%), Gujarat (10.9%) and Karnataka (10.4%) of the total production of the country. The total area under crop during 2000 was 3.5 million hectares with production of 2.79 million tonnes. Though there has been increase in area and production, still there is no break through in the yield levels of crop. The pigeon pea is the crop of arid and semi-arid regions of the country. The crop is mostly raised as an intercrop such as rice-pigeon pea, sorghum-pigeon pea, soybean- pigeon pea etc. One row of pigeon pea is sown and there will be four rows of soybean crop. By this crop based farming the yield of soybean and pigeon pea is more than the yield of soybean as a sole crop or sole crop of pigeon pea. This arrangement helps in proper utilization of nutrients and water during the crop-growing season. In case of rice crop it is raised on the levees surrounding the small plot of rice. It is sown during rainy season and being long- duration crop it is harvested after the rainy season. The pigeon pea grows well on the rice field where level of water is maintained in the field.

The farmers mostly harvest the pigeon pea manually. The crop is collected and dried. It is then beaten to separate the pods and leafy matter. The material is spread on the threshing floor and threshed by bullock treading. The process is tedious and time consuming. The quality of the seed deteriorates. This method is followed as the long and hard stems of plant

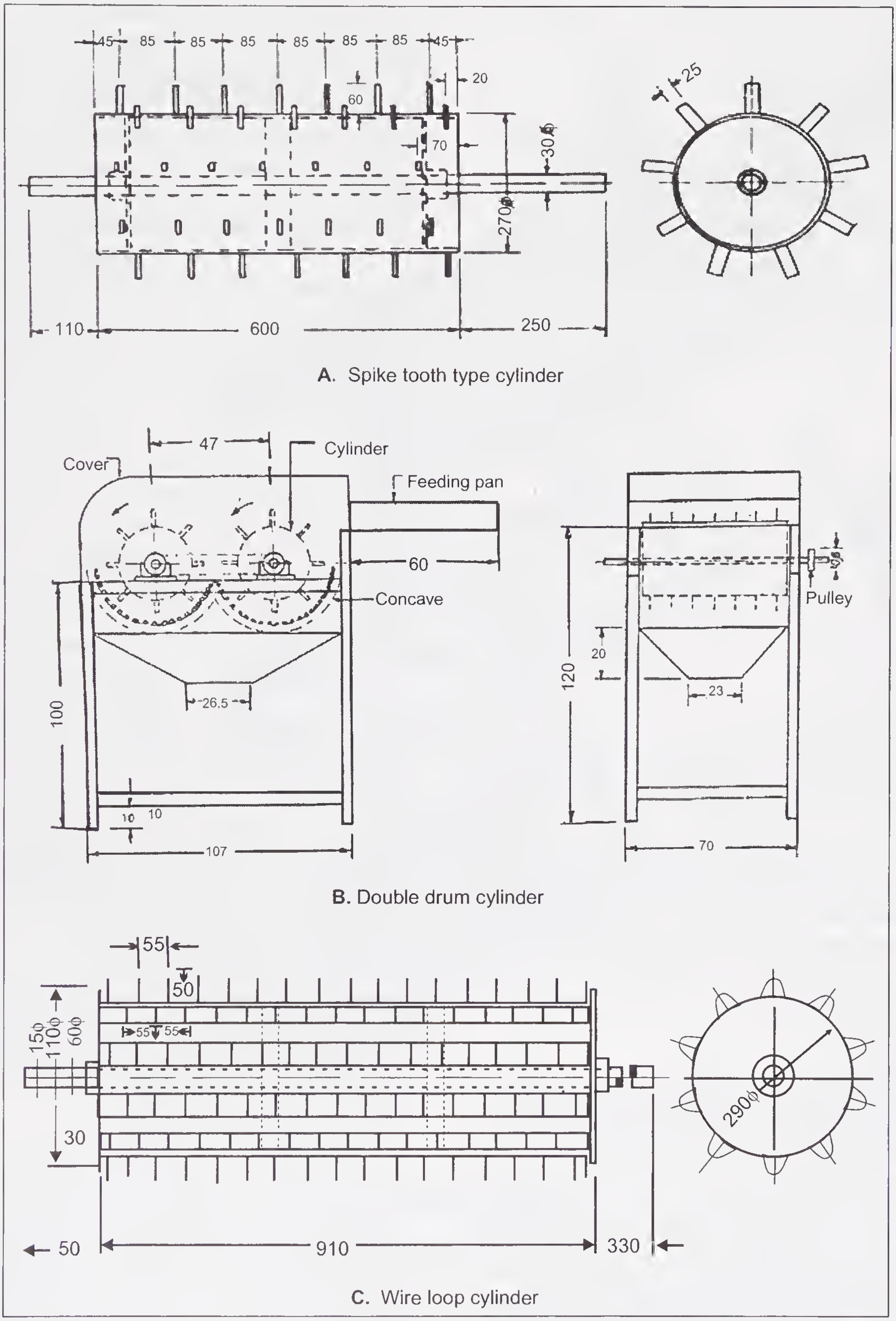


Fig. 9.11. (A-C) Three threshing cylinders evaluated on pigeon pea. (A) Spike tooth cylinder, (B) Double cylinder system; and (C) Wire loop cylinder (*Source:* Neeraj, 1987).

are used as fuel and for covering of house roofs. The work on development of thresher for pigeon pea started at GBPUAT Pantnagar, India from 1986-1987.

Studies on threshing drums: Neeraj and Bachchan Singh (1987) reported the evaluation of threshing units suitable for threshing of pigeon pea. The threshing cylinders selected were peg type single cylinder, peg type double cylinder and cylinder with loop type teeth. These are shown in Fig. 9.11. The cylinders (Fig. 9.11) were mounted on the angle iron frame provided with open concave with grate opening of 6 mm covering 180 degrees of cylinders. The diameter of cylinder was 51 cm. The feeding pan and the gap between cylinder cover was 21 cm for ease in feeding of the crop plants. In brief the threshing mechanism was aimed for stripping the top portion of the plants without damaging or breaking the main plant stems, which are used by the farmers as domestic fuel or roofing material. The cylinders were operated at linear speeds of 13.33, 15.0, 16.66, 18.33 and 20 mps. The concave clearance at the entry and exit were 12 and 28 mm. The crop variety selected was UPAS 120 during the experiments. The performance of three threshing mechanism was reported in terms of unthreshed grain on plant stems, unthreshed pods and total unthreshed grain. It was reported that the per cent unthreshed grain on stalk was not affected by the cylinder speed for the double cylinder threshing unit and it was in the range of 1.73–1.16 %. In case of loop type threshing unit and single drum peg type threshing units the unthreshed grain on stalk decreased due to increase in speed of cylinder. It was because the operator was able to push the plant stem inside, as the top portion was broken inside due to impact of threshing unit. Thus the unthreshed grain on stem varied from 5.33 to 0.94% for the peg type single cylinder and from 5.4 to 1.57% for the loop type cylinder for the speed range of 13.33–22.0 mps.

The damage to grain was more for double peg type cylinder as the grains were subjected to the greater impact forces. The damage was less in the peg type single cylinder unit. The studies showed that the relationship for the pod moisture content was related to the unthreshed grains for all speeds linearly. Thus as the cylinder speed increased the unthreshed grain per cent decreased. At high moisture level of pod the unthreshed percentage was more due to high attachment strength of

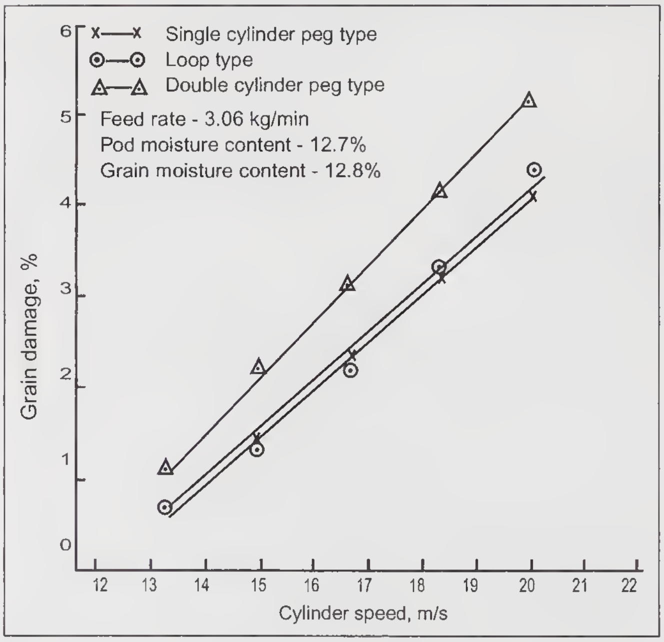


Fig. 9.12. Performance of three threshing cylinders on threshing of pigeon pea.

pods. The pods are tough at high moisture level. During the experiments the moisture level were varying from 8 to 17 %. To detach pods from stems and separate the grain the impact forces required were high at high moisture level and at low moisture level the high threshing efficiency were achieved even at lower cylinder speeds.

The effect of cylinder speed on the germination percentage was in the range of 94-87 % from the low to higher cylinder speeds. It was concluded that there is no difference due to the threshing unit on the germination percentage of seed.

Thus the performance of single-peg type cylinder and the wire loop type cylinders were

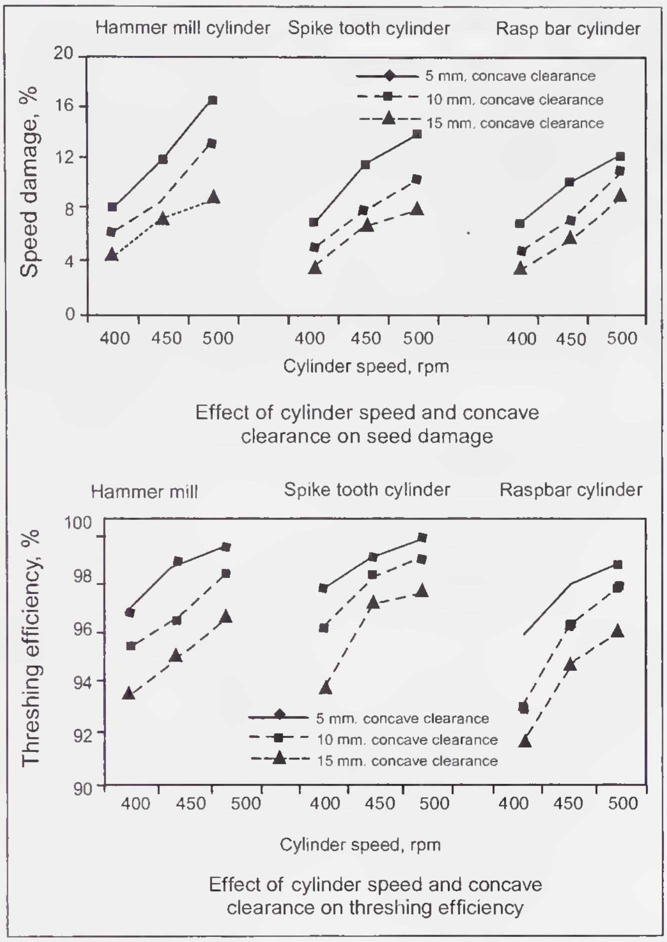


Fig. 9.13. Effect of different cylinders' speed, concave clearance on threshing efficiency and seed damage.

reported satisfactory for use on the pigeon pea thresher (Fig.9.12).

Lohan *et al.* (2007) conducted studies on three threshing units viz. Hammer mill, Peg type and Rasp bar type threshing units on pigeon pea crop variety "Manak" at 10.5% moisture content at three threshing drum speeds (400,450,500 rpm) and with three concave clearances (5, 10, 15 mm) at HAU, Hisar, India (Fig. 9.13) to determine the suitability for getting pigeon pea seeds of quality and with high germination percentage. The analysis of experimental results indicated that threshing efficiency of threshing cylinder decreased with decrease in cylinder speed and again as the concave clearance increased from 5 to 15 mm. The minimum of seed damage was reported for low speed and high concave clearance. The spike tooth cylinder with 400-rpm speed resulted in seed with germination percentage of 81% at 15 mm concave clearance. The threshing efficiency for the above operating condition was 92.5%. The maximum seed damage was 16.54% for the hammer mill type-threshing cylinder. It was concluded that spike tooth cylinder performance was better as compared to other units tested.

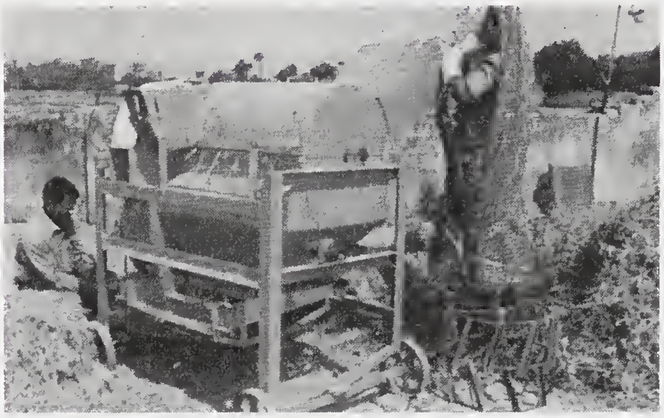


Fig. 9.14. Threshing of pigeon pea with CIAE multi-crop thresher at Bhopal.

CIAE-multi-crop thresher (Fig. 9.14) was also evaluated on the pigeon pea crop. For conducting threshing studies the pigeon pea crop was subjected to stripping action by which the top portion of plants were separated from the hard portion of stem for conduct of the experiments. The thresher cylinder is of peg type. The pigeon pea variety selected was JA3. The moisture content of grain was 7.5% and the straw moisture was 9.5 %. The trial showed that the thresher was able to thresh the crop with grain output of 98 kg/h, cleaning efficiency of 95.1%, threshing efficiency of 99.5%, the spilled grain was 0.11 %, blown grain was 0.16 % and seed damage was 0.21%. The cylinder was operated at linear speed of 9.2 m/sec.

Based upon the number of trials conducted at Bhopal the thresher setting for pigeon pea recommended are, cylinder speed 7 mps, aspirator blower speed of 30 mps, concave clearance of 15-20 mm, the gap between concave bars is 7 mm, sieve stroke length was

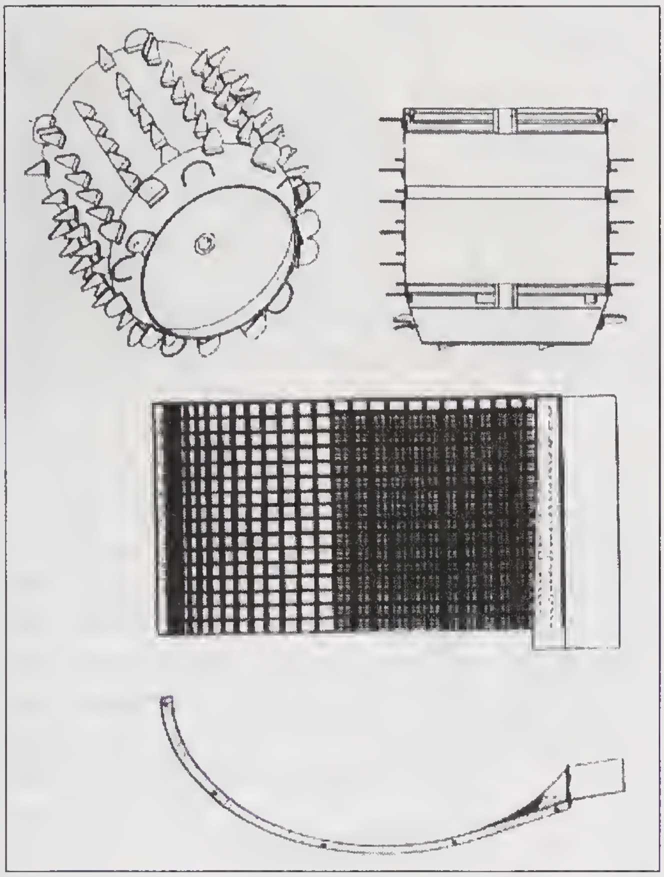


Fig. 9.15. Threshing cylinder and concave used on pigeon pea thresher for threshing top of plant portion.

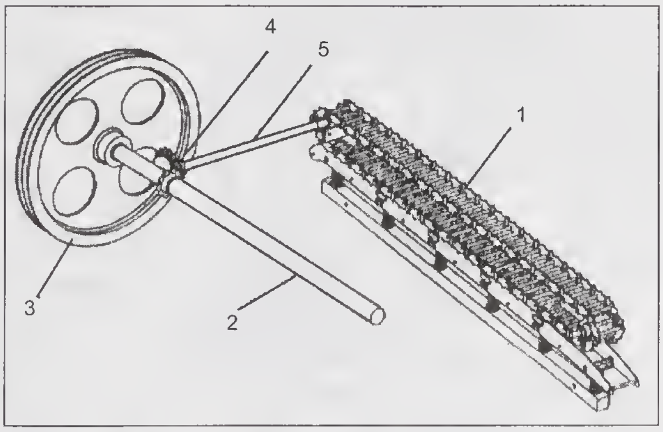


Fig. 9.16. Crop bundles feeder chain used on the thresher. 1, Conveyor chain; 2, Shaft; 3, Drive pulley; 4, Bevel gear drive; 5, Shaft.

24 mm, sieve hole size of 8 mm, sieve slope of 2.0 to 2.5 degrees. It was reported that the crop output was low because the percentage of grain in the crop plants is around 29%.

Fig. 9.17. Modified pigeon pea thresher for threshing of crop on the farm at Bhopal.

Pigeon pea thresher with crop feeding chain conveyor (Fig. 9.15, 9.16, 9.17): A thresher for threshing of pigeon pea was developed at CIAE, Bhopal, with the aim of saving the plant stalks completely for use at the farm for domestic purpose. Thus, it is the thresher fitted with feeding chain device, which holds the plant stalks during threshing of top portion of the plants. The feeding system is similar to that used on the automatic rice thresher. The crop bundles of pigeon pea crop are fed continuously one by one from the feeder end of the cylinder and discharged at the other end of the threshing cylinder. The cylinder is closed type and its diameter at the feeding end is 765mm and gradually increases to 895 mm. The cylinder is tapered at the feed end to grasp the unthreshed top end of crop bundles. The cylinder is 754 mm in length and 718 mm diameter at crop ejecting end. The concave is made of wire mesh of 15mm mesh size and supported by concave of 6mm diameter bars. The concave covers 120 degrees of cylinder. The crop stems are held on the crop conveyor chain and poded portion of plant is fed into the threshing unit. The concave is covered with the wire mesh in the initial portion at the entrance (feed inlet) to prevent the fall of the detached pods through the grate due to initial impact of cylinder pegs. Thus the pods are impacted and the rubbing action also takes place due to rough concave surface and cylinder, and thus grains are separated. The rotation of cylinder

pushes out the grain and fine chaff out of the concave grate.

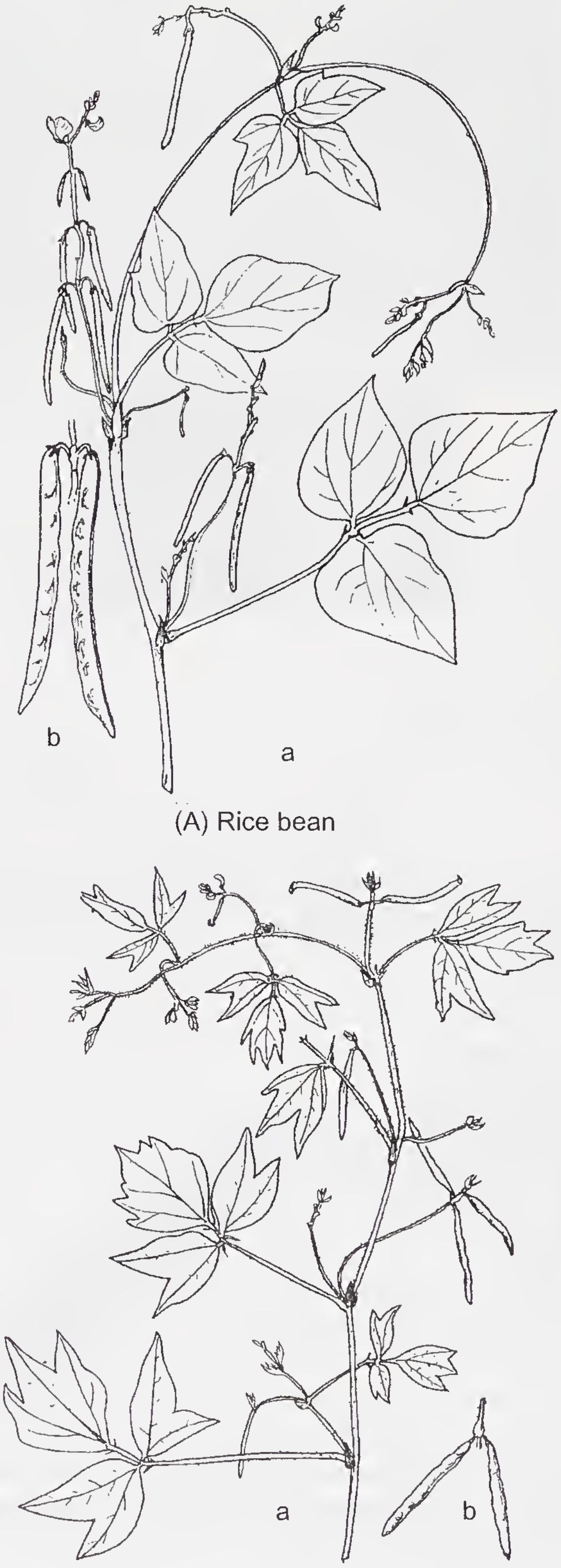
Thus the mixture of grain and straw falls on the cleaning sieves. The feeder chain of the thresher carries out the stripped plant stalks stems. The aspiratory blowers and the cleaning sieves with shaking arrangement achieve the cleaning of the grain. A 7.5 kW motor powered the thresher.

Performance data of the pigeon pea thresher:

1.	Crop feed rate; in kg/h	1667-1752
2.	Grain output; in kg/h	384-420
3.	Threshing efficiency; %	97.6-98.4
4.	Cleaning efficiency; %	93.8-97.4
5.	Blown grain: %	0.04-0.07
6.	Sieve overflow; %	0.49-0.64
7.	Broken grain %	0.35-0.58
8.	Grain overflow through bundle outlet;	0.08-0.14
9.	Unthreshed pods left on plant; %	1.35-2.1

a. Branch b. Pods

Fig. 9.18. An apical portion of a branch of French bean (*Rajmash*) and pod.



(B) Moth bean

a. Branch b. Pods

Fig. 9.19 (A-B). An apical portion of branch and pods for rice bean and moth bean.

10. Overflow through feed inlet; % 0.05 to 0.09
11. Straw loss; % 3.5

The thresher required 5 workers to operate it at the above feed rate. The cost of threshing for pigeon pea was reported as ₹ 350/ tonne of grain based on year 2006-2007 price levels. Thus a pigeon pea crop thresher was designed at CIAE, Bhopal, as per the requirements of the farmers with a capacity of 400 kg/h of grain.

Beans

The other pulses are beans (kidney bean), rice beans and moth beans (Fig. 9.18, 9.19). These beans are also consumed as vegetables when they are in green state and tender. The crop when matures the beans are harvested and beans are consumed as pulses by the people. The plants of these crops are also branching type and semi erect type.

The bean plants are harvested completely and brought on the threshing floor for drying and threshing. The plant material of these plants is used as animal feed. Therefore farmers are interested in saving of grains and entire plant mass. The details of threshing pulses indicate that the threshers described can be also used for these crops. The care is to be taken to see that concave have opening size more than the characteristic dimension of seed. The cleaning shoe sieve is selected accordingly to suit the size of seeds. The farmers in Asian countries would like to have clean grain and all the material therefore the emphasis would be more on saving of grain and straw completely. As the production of pulses are on small scale the size of thresher will be of small size say within 5 hp size.

HAU Axial flow pulse thresher (Fig. 9.20)

Bansal and Lohan (2009) reported the

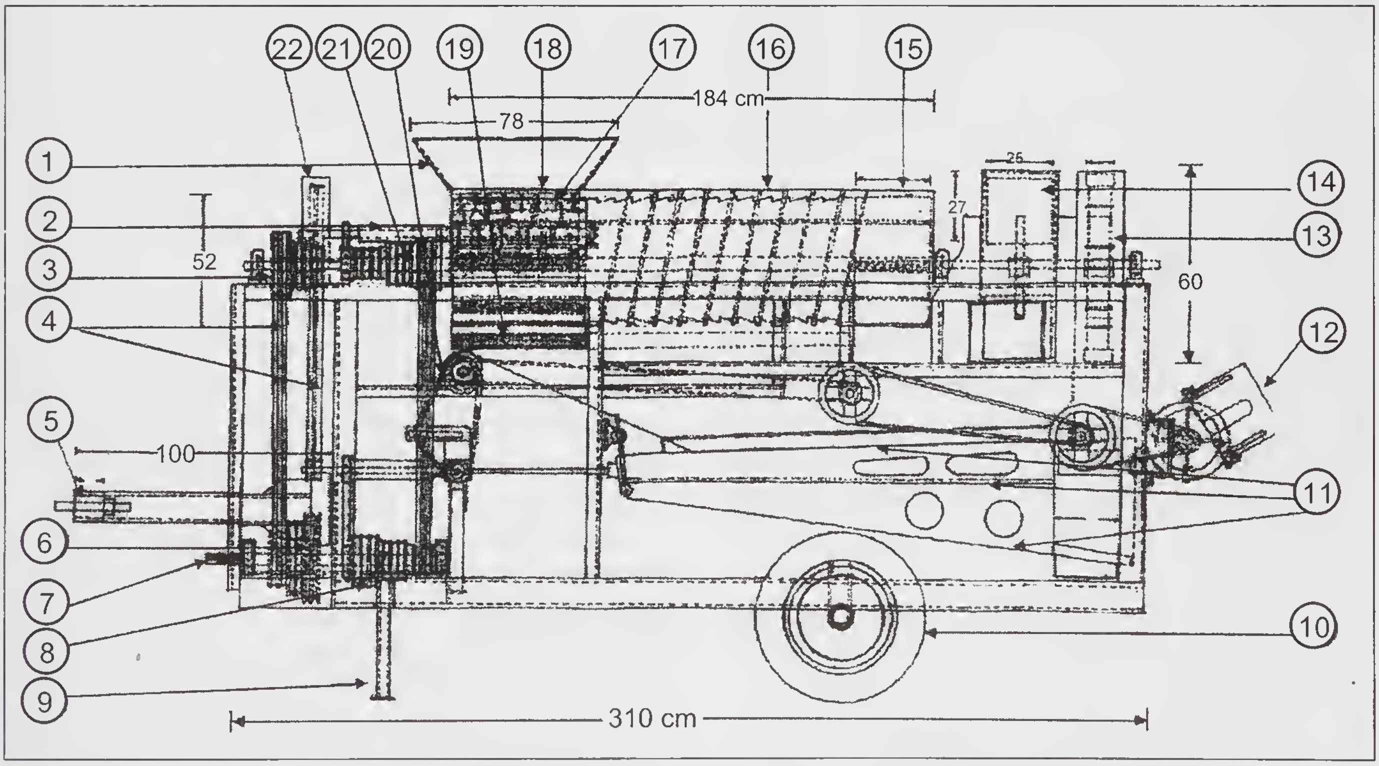


Fig. 9.20. HAU axial flow thresher for pulses for seed purpose. 1, feed inlet hopper; 2, feeder shaft; 3, pulley for aspiratory blower; 4, v-Belts; 5, hitch, 6, 3-step driver pulley; 7, power input shaft; 8, threshing drum pulley; 9, Stand; 10, Transport wheels; 11, sieves; 12, rear blower; 13, blower; 14, aspirator; 15, straw thrower; 16, separating unit; 17, threshing unit; 18, rasp bar cylinder; 19, concave; 20, belt conveyor; 21, pulley for cylinder; 22, feeder pulley.

development of an axial flow thresher for threshing of pulses so that the seed damage is less during threshing. The thresher was developed to meet the requirements of the university which was producing seeds of pulses for supply to the farmers in the state. The traditional thresher available caused the seed damage of 14.32%. Therefore an axial flow thresher was developed using rasp bar type threshing unit and a concave with adjustable clearances and speeds of operations for threshing drum and blower. The unit was designed to be operated with tractor or an electric motor of 7.5 kW. A hopper type feeding unit of 780mm length with auger type feeding device was provided. The auger had finger type feeding unit to have positive flow of material in the threshing unit. The threshing unit required the lower cylinder speeds from 8 to 19.6 m/s. The cylinder speeds could be set at 8.2, 9.5, 11.0, 12.2, 14.7, and 19.6m/s for threshing the pulses. The cylinder diameter was 520 mm and 515 mm long. The cylinder was mounted on shaft of 55mm diameter. The separating portion of the threshing drum was 995 mm long and 550 mm in diameter. The concave grate with a fixed opening of 15 mm was provided. The top cover of concave was fitted with louvers of 23 mm width for helical movement of the crop. The louvre spacing was 100 mm. Thus the threshing and separating length of cylinder was 1510 mm the seed separated was moved by means of a conveyor belt to the cleaning sieves. The cleaning sieves were also provided according to the size of thresher. The sieve size was 1060×510 mm.

An aspiratory blower was provided to clean the threshed crop. Beside other blower was provided for further cleaning at the sieve grain outlet. The performance of thresher was reported on threshing of green gram, black gram, chick pea and soybean. The crop moisture level varied from 10 to 14% only in chickpea initial level of M.C. was 7.8%.

Based on the results reported it was concluded that pulses as mentioned above were threshed with the machine at threshing efficiency of 95% at germination percentage of 88% for green gram, 90% for black gram, soybean and chick pea 90% with visible seed damage within + - 2% when cylinder speeds were in the range of 8-9m/s. The high threshing efficiency was achieved with high cylinder speeds but the seed damage was also high. The cleaning efficiency were in the range of 90-93% when moisture content of crop was low. These results have been also reported with axial flow thresher developed at CIAE, Bhopal and other places.

Thus there are threshers developed for threshing of pulses. The crops where pods are attached all over the branches, entire plant mass is to be fed into machine, as in case of soybean, bengal gram, green gram and black gram. In case the pods can be detached from the plants the radial flow type thresher can be used. In case of top portion of the plant is full of pods such as pigeon pea the thresher with feed conveyor chain is used to thresh the crop. The stripping type action may be required to strip the pods and the spike tooth type cylinder (rice crop) is used to strip the pods from plants.

In case of other pulses the CIAE has developed the plot thresher which can be used to thresh these crops. This thresher is very simple and low cost. It would meet the requirements of the small farmers raising pulses.

The axial flow threshing cylinder can be effectively used to thresh most of the pulses. The threshing speeds are to be set in the range of 8-10 m/sec. The concave at the initial feeding zone be blanked to help in removal of husk and not allowing the pods slip through the concave openings. For rice bean, moth beans the size of top sieve of cleaning unit are to be adjusted. Normally the grain quantity is less and plant material is more. However farmers want to recover all grain

and plant material as both are valuable to them. They prefer to have grains along with some trash rather than lose the seed in chaff. As the sale value of pulses are much higher than the cereal crops the demand for thresher for pulses is increasing from the farmers. In most of the threshers the cleaning efficiencies reported are less than 90%. This means that threshed grain is to be passed one more time through scalper or cleaner to achieve desired level of cleaning efficiency.

❑

10 Threshing of Oilseeds Crops

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Groundnut threshers

India is the largest producers of oilseed crops in the world and paradoxically the largest importer of edible oil. Groundnut is the major oilseed crop of the country accounting for 45% of oilseed area and 50% of oilseed production. The traditional methods of production and processing are prevalent in the country. These are mostly labour intensive. The groundnut crop is harvested by country plough or blade harrow and the crop is left in the field for drying. The groundnuts pods are separated from the plant material either by manual pulling or beating the plants on wooden plank. The pods are separated from straw and vines by winnowing. The output by manual methods is low. It varies from 10-15 kg/man-h. However the traditional system of operation survives because the farmers are interested in the entire biomass produced. Secondly they help the rural labour force by providing some jobs to them. The green tops of the plants are used, as animal feed hence no portion of crop is wasted. The farmers mostly sell the dry or freshly harvested groundnut pods in the market. They use decorticate to separate kernels from pods either for seed purpose or for consumption at home.

For mechanization of threshing and decortications operations, a number of equipment and machines were developed to meet the needs of small farmers. Of course the greater attention was paid to identify suitable equipment for threshing and decortication of groundnuts during 1989-90 which helped them in boosting the production and productivity levels of oilseeds. During this period the government of India, through Indian Council

of Agriculture Research, New Delhi launched an oilseed production programme to enhance the production at the national level involving state agricultural universities, research institutes, private institutions and ICAR extension programmes. In case of groundnut crop the pods are to be stripped from the complete mass of harvested plants. In some cases the farmers allow the plant tops to be harvested first and then the pods are dug out. As in Asian countries the haulms are used as animal feed and therefore complete plant is harvested on the farms. Thus farmers have to perform the two operations i) stripping of pods and ii) shelling or decortications of pods. The stripping of pods is done at high moisture level and after the pods are dried they are stored or sold in the market. High moisture pods after stripping have got to be dried either for long time storage or for disposal in the market. Shelling is done to consume the groundnuts at home or used as seed for sowing of the next crop.

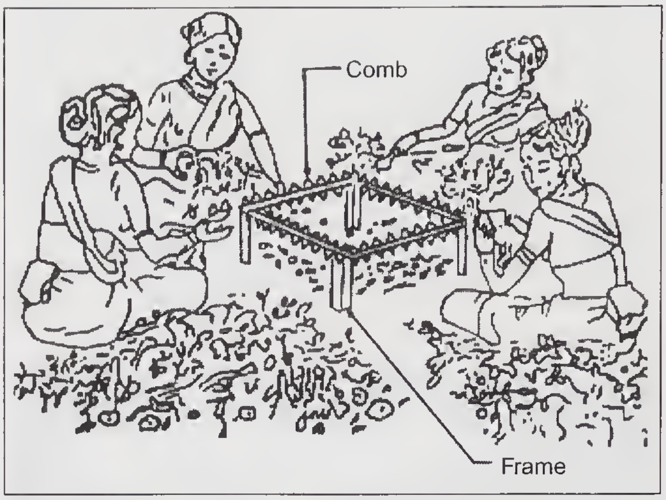


Fig. 10.1. Groundnut pod stripping bench.

Groundnut pod stripper

The pod stripping devices used in the country were either stripping bench (Fig. 10.1) or stripping drums (Fig. 10.2). The stripping bench consisted of square frame with metallic strips fixed on the four sides in the form of comb and provided with legs of 30 cm height. The four women worker would sit along the four sides and by drawing the crop vines on the sides would strip the pods. These were introduced in the states of Tamil Nadu and Andhra Pradesh. The output per worker was reported as 10-15 kg/ man-h.

Manual and power operated drum type stripper for pods were also developed at Coimbatore, India. It consisted of cylinder made out of four or six mild steel rods covered with rubber tubing and provided with two discs at the ends to form the shape of a drum (Fig.10.2). The shaft provided at the centre is mounted on two bush bearings. The unit is mounted on the frame of angle iron. The

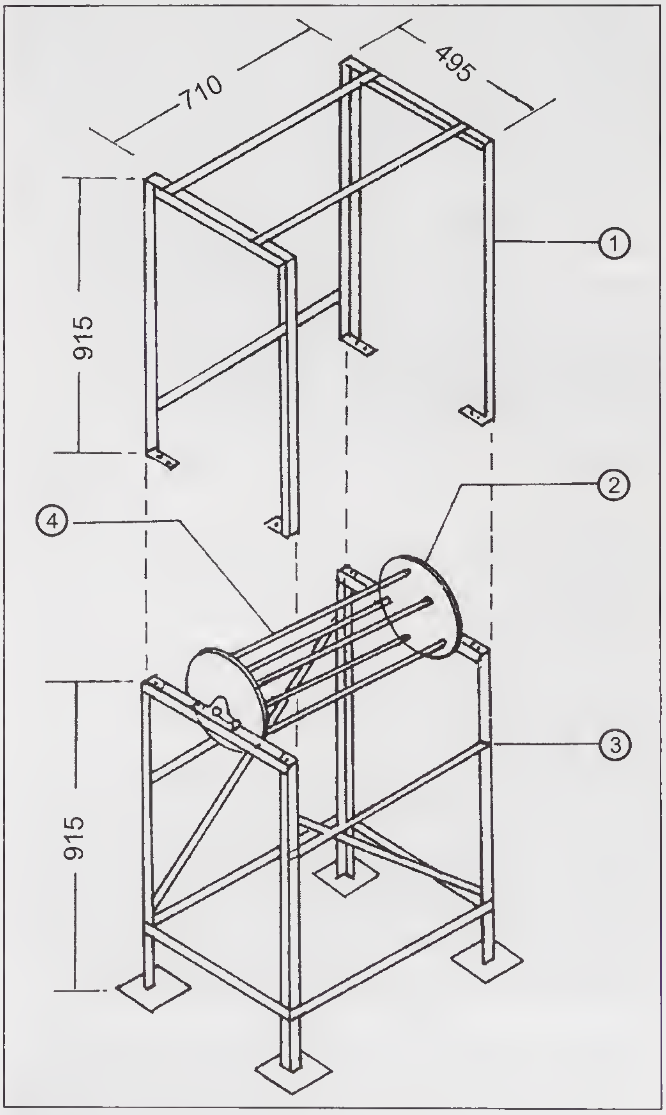


Fig. 10.2. Rotary drum type groundnut pod stripper. 1, frame for covering hood; 2, revolving drum; 3, frame; and 4, rubber coated bars for stripping.

operator takes a bunch of crop and beat over the bars. Due to impact and rubbing action the pods are detached from the vines. The pods fall below in a tray and when all the pods are removed the plant material is thrown away. Again a fresh bunch is taken for stripping. It was reported that the output of a unit was 20 kg/man-h. However for the motorized unit the output reported was 25 kg/man-h.

Pedal-operated groundnut pod stripper/ winnower

It is a pedal operated machine for stripping the pods from the harvested crop. It consists of stripping drum and also the winnower (blower type), which is operated by the pedal lever to convert the up and down motion, into rotary motion. It is rotated at about 70 rpm. The crop is fed through the feeding chute into the stripping unit. The stripped pods are allowed to fall into the perforated trough. The straw and light material is blown away by the winnower. The drum and winnower are mounted on the same shaft. The dimensions of machine are length 710 mm, width 690 mm, and height 1,020 mm. The weight of machine is 37 kg. About 10-15 kg/h of pods with vines are stripped. The machine (Fig.10.3) is locally manufactured and sold in Thailand. The cost of machine during 1993 was approximately US $170.

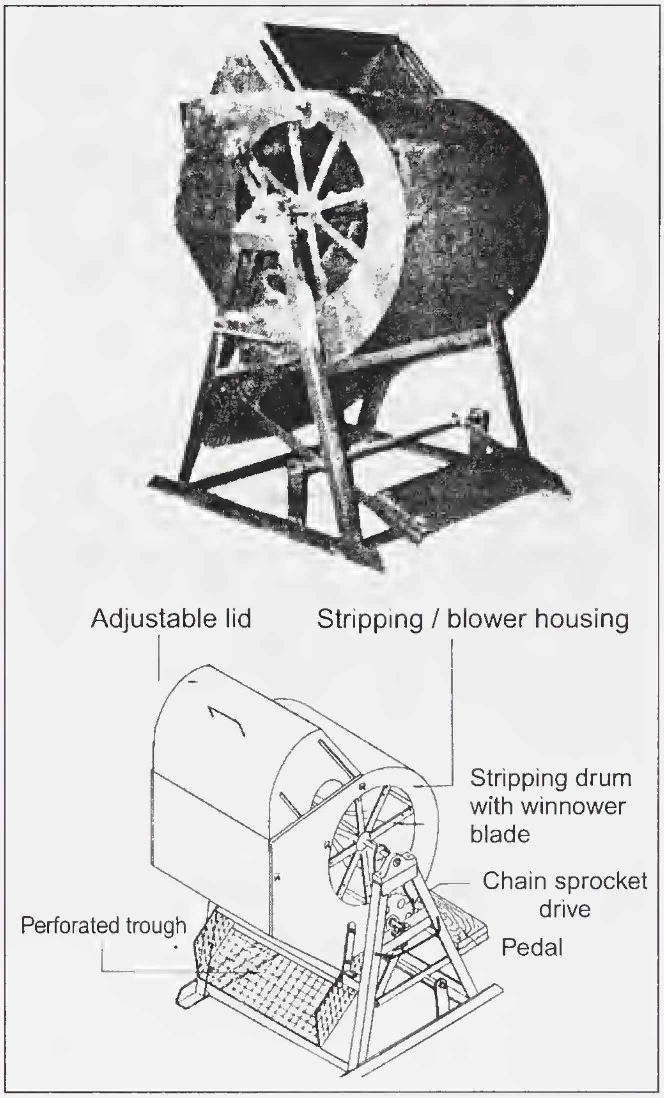


Fig. 10.3. Pedal-operated groundnut stripper developed in Thailand.

APAU motorized drum type stripper (Fig. 10.4)

It is a motorized drum with wire loop type teeth mounted on the frame. The pods are held near the rotating drum where they are stripped and are collected in the tray. The stripped bunch is then thrown on one side and fresh crop is taken for the stripping action.

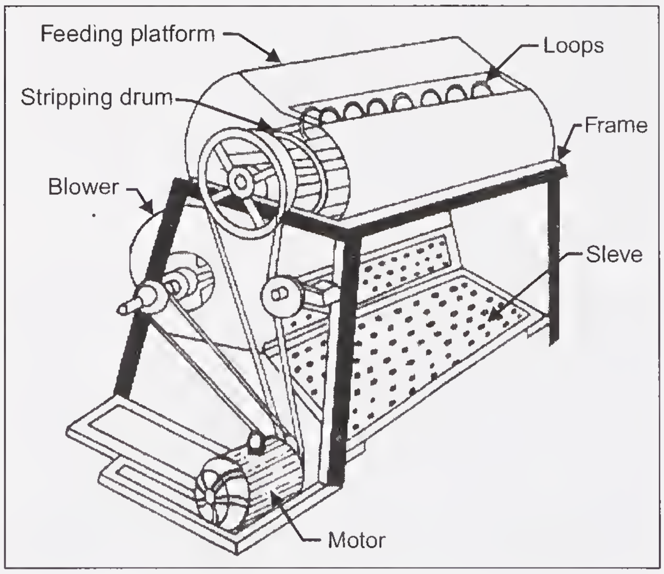


Fig. 10.4. APAU motorized drum type stripper.

Whole crop throw-in type groundnut thresher

The thresher (Fig.10.5) was developed at PAU Ludhiana to be operated by tractor and 5 hp electric motor for threshing of sun dried crops. The output of thresher with

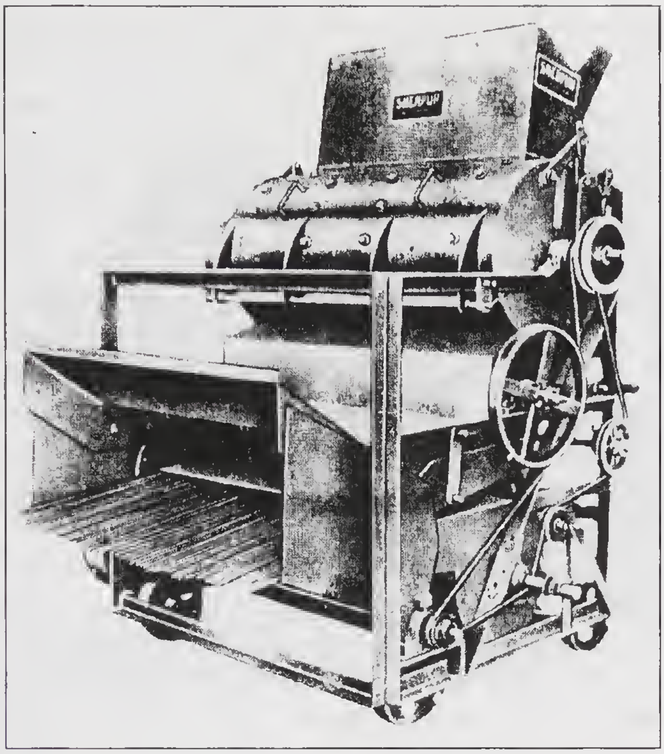


Fig. 10.5. 'PAU' power operated groundnut thresher.

tractor operation was reported as 300kg/h when operated at cylinder speed of 6-7 mps. It consisted of feeding trough, threshing cylinder, concave, oscillating rack, air blower, cleaning shoe with stammer saws, set of sieves, auger conveyor and transport wheels. The spike tooth cylinder was similar in design as for wheat thresher, but the numbers of spikes for this cylinder were reduced to half to avoid pod damage during threshing. The concave was made of round bars of semi circular shape with rectangular opening of size 60 × 30 mm to allow the stripped pods to fall on the rack. The concave clearance was maintained at 19 mm.

Three rows of stammer saws are provided in cleaning shoes to cut up plant roots and vines. The direction of rotation of saws was in clockwise and anticlockwise directions. Screens separate the pods and the light material is blown away by the air blast. The output of thresher when operated with tractor PTO was 300 kg/h with cylinder speed of 6.5 mps. Only dry crops were threshed with the machine. The wet crop caused the choking of the threshing unit.

TNAU groundnut thresher: A groundnut thresher for threshing of freshly harvested crop was developed at Coimbatore (Fig.10.6). It consists of a feed hopper, flow through type spike tooth threshing cylinder, concave, haulm remover, oscillating sieves, blower and power transmission system.

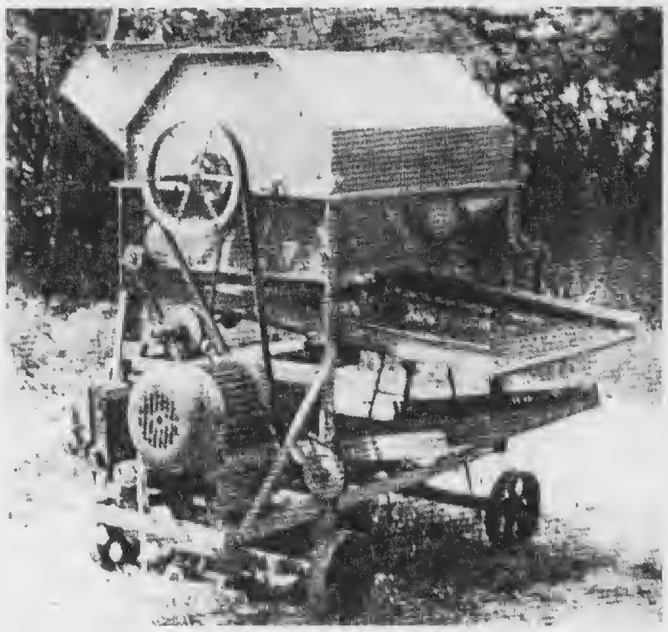
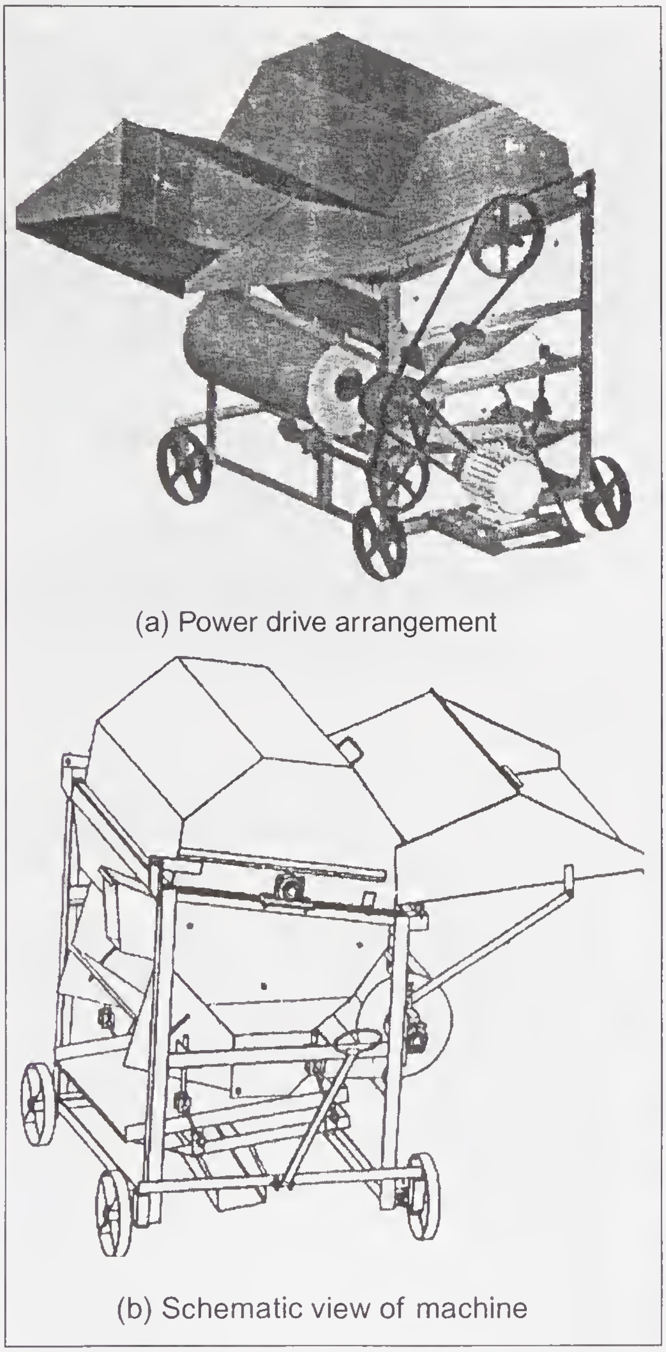


Fig. 10.6. TNAU groundnut thresher for freshly harvested crop.

The parts are mounted on an angle iron frame. The crop is fed into the threshing unit and pods are separated from the plants due to combing and beating action at the concave as well as threshing cylinder. The stationary pegs on the concave prevent the rolling of vines over the cylinder. The threshed material and pods fall on the oscillating sieves. Here the pods are separated from the vines and straw with the help of blower. The performance trial indicated that the thresher had an average pod output of 106 kg/h at the cylinder speed of 6.2 mps. The threshing efficiency was 96 %, the blower losses were in the range from 2.7 to 6.1% and shelled pods were reported from 3.6 to 6%.

CIAE groundnut pod stripper: During 1990,

development of power operated groundnut pod stripper for the freshly harvested crop was initiated at CIAE, Bhopal, to meet the needs of groundnut growing farmers in central and other states. The groundnut stripper (Fig.10.7) consists of a feeding tray, spike tooth type threshing drum, concave grate, stripping bar, cylinder top cover, straw thrower, blower and pod collection pan. The axial flow principle was used in stripping the pods from the crop, which is at high moisture level. The concave used has opening size of 50×70 mm to allow the detached pods to fall through the concave. The axial flow principle is used to strip the pods from the freshly harvested crop. The louvers are provided in the top cover to retain and rotate the crop in the threshing unit to strip the pods from the plant haulms. The stripping bars also prevent the vines from wrapping on the spikes or cylinder. The plant vines and leafy material is moved axially along the cylinder length and is ejected through the unit by the straw thrower provided at the other end of cylinder. The pods along with light leafy material and vines fall through the concave and are subjected to the air blast from the blower and get blown off. The pods fall into the collecting pan.



(a) Power drive arrangement

(b) Schematic view of machine

Fig. 10.7. CIAE groundnut pod stripper for freshly harvested crop.

The output of stripper was noted in the range of 216 to 320 kg/h of pods at moisture content from 48 to 70% on dry basis. The stripping efficiency was 99.6%.

Commercial groundnut threshers (Fig. 10.8, 10.9): The commercial models of groundnut threshers are available and used in the groundnut growing area of Gujarat

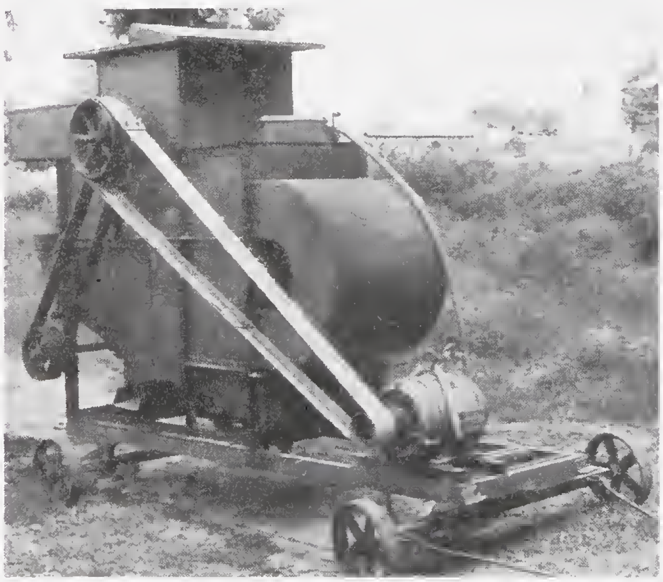


Fig. 10.8. Commercial thresher for dry crop of groundnut crop.

Fig. 10.9. Groundnut thresher for dried crop developed in collaboration with CIAE, Bhopal.

and Andhra Pradesh. These machines are designed for threshing of completely dried crop. The entire mass of crop is fed inside the machine, which is fitted with spike tooth type cylinder and concave. The entire mass of plant material is broken up into small pieces to fall through the grate. This results in low output, poor cleaning efficiency and more of seed damage. The sun drying of crop increases the field losses due to birds and rodents for the farmers. The commercial threshers consist of threshing unit of spike tooth cylinder and concave with cleaning shoe. The crop is fed on the top of hopper. The dry crop mass is broken by the cylinder and the pods are separated there. The pods and plant material falls on the cleaning shoe screens where the light material is blown away and the pods are collected at the outlet. These units are powered by 5-7.5 hp electric motors and the output of machines is in the range of 100-150 kg/h.

The groundnut thresher for the freshly harvested pods has been developed and is commercialized through a company in Jasdan, Gujarat. The commercial machine has been supplied to ICRISAT, Hyderabad, and the performance of the machine was reported to be 99% stripping efficiency and with cleaning efficiency of 98 %.

Groundnut decorticators

TNAU decorticator: TNAU, Coimbatore had developed the decorticators of manual and power-operated units based on principle of rubbing action with the spiked shoes in the open semicircular hopper. It is similar in design

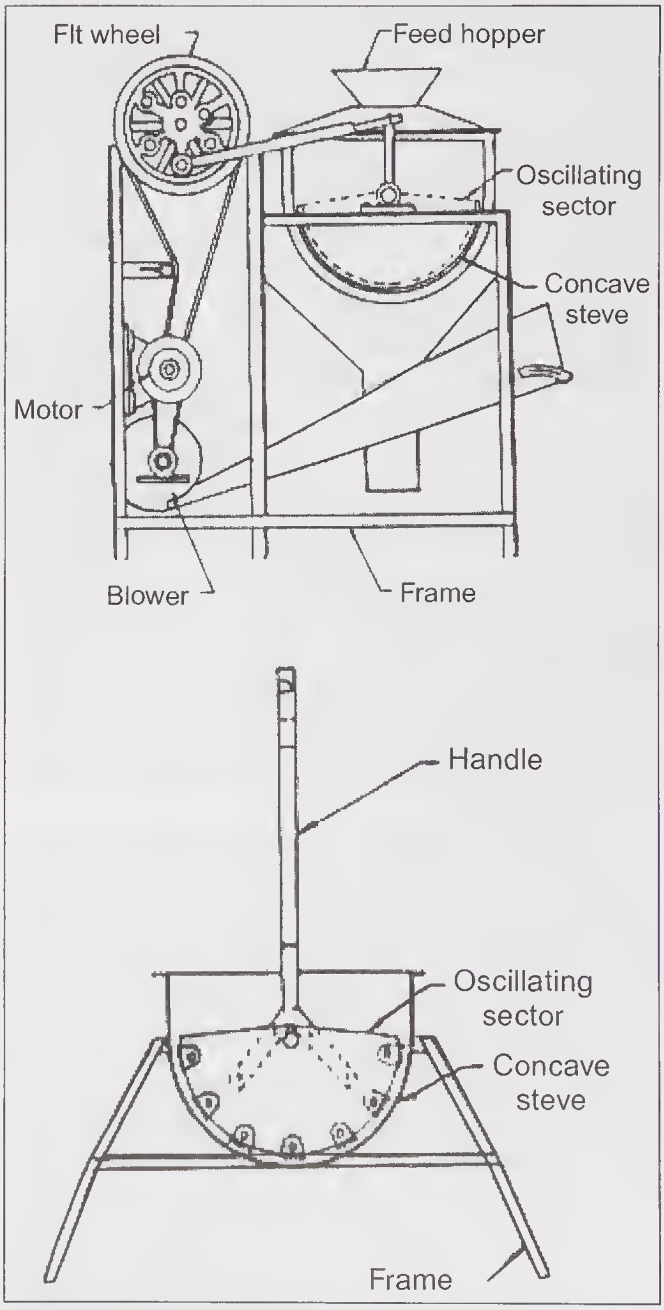


Fig. 10.10. TNAU power operated and manual swinging shoe type decorticators.

to the unit developed at Tropical Product Institute, UK. The decorticators are shown in Fig. 10.10. The weight of manual decorticator was 40 kg. It had a hopper with base which was fitted with the sieve with elongated slots. The seven shoes with peg type projection are mounted on the semicircular bracket fitted with a long handle. The assembly is mounted on two bush type bearings and the unit is moved in to and fro motion by the handle. The unit hopper is filled with pods and the handle is given oscillating motion. The rubbing action of shoes on the pods helps in breakage of shells and kernels are separated. The motion of handle moves the kernels out of grate and fall into the tray along with shells. The entire shelled mass is collected and cleaned by winnowing action or by a cleaner.

The performance data of manual decorticator reported was as follows: shelling efficiency 95.5%, breakage 1.26% and output 76 kg of pods per hour using three female workers. The power-operated unit is powered by 1.0 hp motor and is provided with cleaning blower. The output of machine reported was 230 kg of pods per hour, shelling efficiency was 97.65%, cleaning efficiency was 99 % and breakage was 2.27%. This was achieved by employing one male operator. The moisture content of pods was 4.12% and the kernels had moisture content as 2.64%. The kernel per cent in pods was 75%.

CIAE groundnut pod decorticator: The sheller design is based on the same principles as used in 'TNAU' and other designs. The unit consists of a hopper made of mild steel (M.S.) sheet and angle iron. The numbers of oscillating shoes were reduced to three instead of five on other machines. The height of handle is lowered to make it convenient for the operator. The screen is made of steel sheet, punched with four and three rows of slots of 9×45 mm size alternatively. The pods are filled in the box and the lever is moved in to and fro motion. Due to rubbing action of the shoes against pods on screen, they are broken and the kernels are separated. The dimensions of machine are made to suit the local operators to operate conveniently. The kernels and broken shells of pods fall below and are winnowed and cleaned separately. The capacity of machine was reported 40-50kg/h, with shelling efficiency 93-96%. The seed damage was 4-5 %. The cost of the simple machine was ₹ 350 (US $ 8.0) which was easily affordable to all categories of farmers.

In design of 'CIAE' groundnut decorticator the various parameters were considered. This included the crop variables (pod size variation), physiological load on the operator and the ease of operation. The machines were to be supplied to the farmers in the country

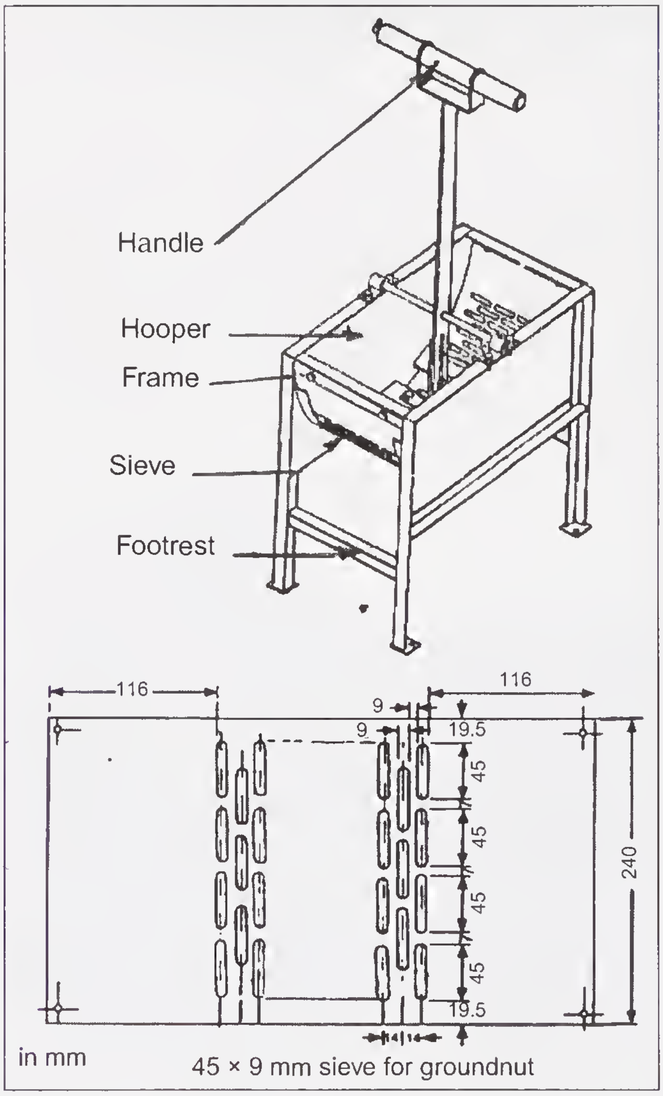


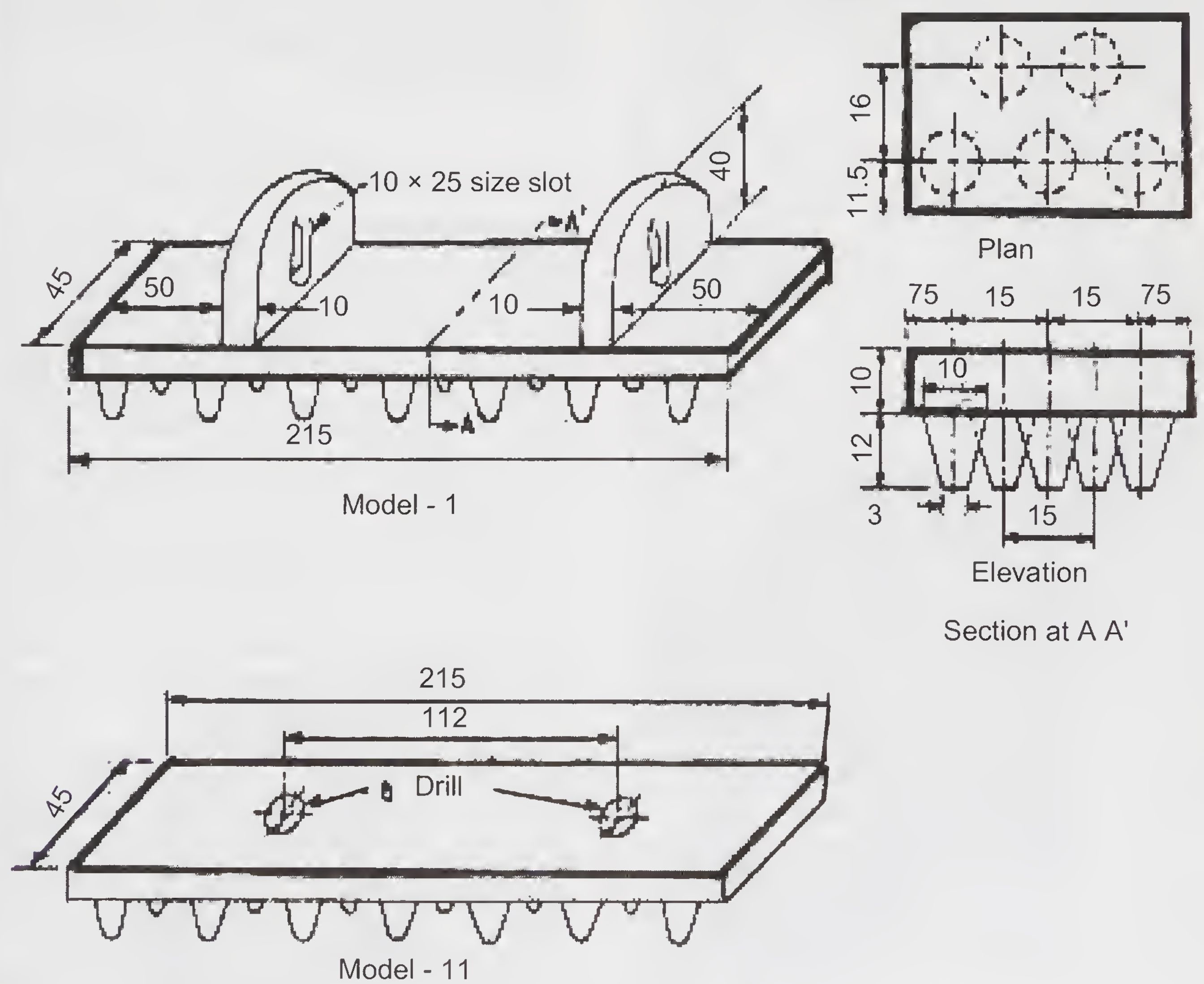
Fig. 10.11. CIAE groundnut decorticator manual type.

therefore the design was made suitable to be packed and forwarded economically.

The two main components of decorticator are the shelling shoe and the concave sieve. These are shown in Fig.10.11 and 10.12.

The sieve used was made from sheet with slots of size 9×45mm with effective opening area of 0.053 m². The shoe was made of cast iron teeth with conical shaped projection. For trials the size distribution of pods and kernels were determined for groundnut variety JL-24 widely used in groundnut producing area of India. The average size of pods were 30.41 mm length, 13.27mm width and 11.97 mm thickness. The kernel length was 16.73 and its average diameter was 8.74 mm. The pod moisture content was 6.8% on wet weight basis. The decorticator was operated at uniform speed of 50 cycles/min. The output of sheller was reported as 55-60 kg/h with 4-5% seed damage.

Improved CIAE groundnut pod sheller (Fig. 10.13): To improve the manual groundnut sheller additional research and development work was carried out at CIAE Bhopal, to study the design from performance optimization



All details as per dimensions - mm

Fig. 10.12. Decorticator shoe.

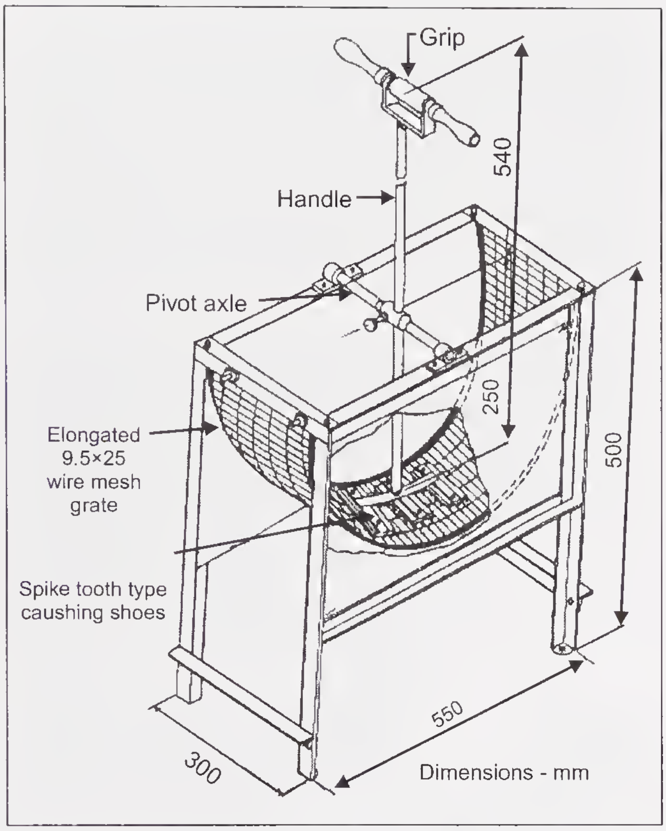


Fig. 10.13. Manual decorticator with wire-mesh concave.

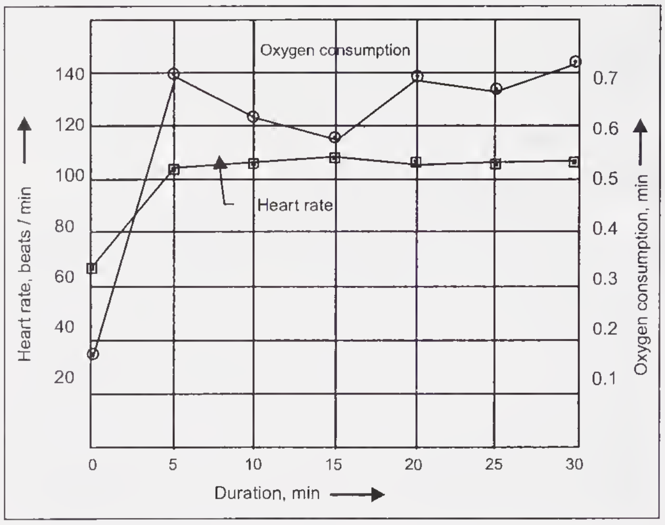


Fig. 10.14. Heart beat rate and average oxygen consumption of the operator during 30 min. test period of decorticator.

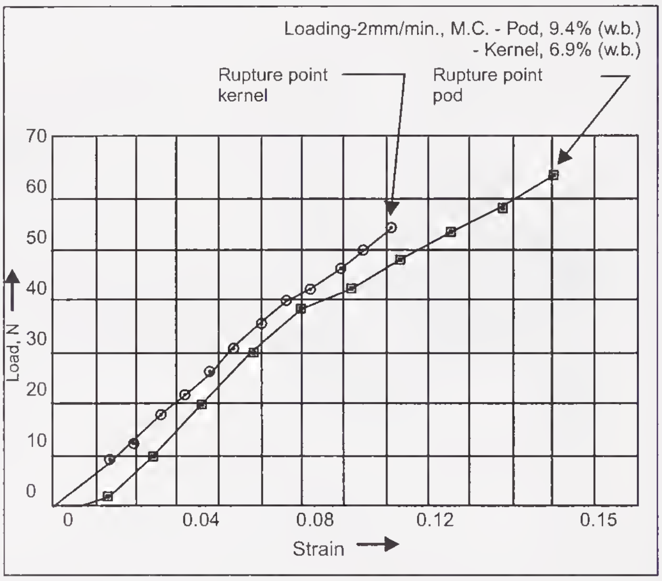


Fig. 10.15. Force deformation relationship under compressive loading of groundnut pod and kernel for JL-24 variety.

and further to consider the convenience of the operator. Singh (1993) reported the development of improved pod sheller. It was based on the same design principles of rubbing and squeezing action. To improve the output of unit the concave sieve was replaced with a wire mesh type grate. The unit was modified to adjust the concave clearance easily. The instrumentation was used to measure the force required to break the pods. The effort put in by the operator during operation was also measured. The physiological load on the operator was measured in terms of increase in heart beat rate and oxygen consumption.

The effort required at the handle grip for breaking the pods was measured by the strain gauge dynamometer and the values reported are 69 N by a normal field worker. This force was within the normal limit for continuous pull and push action. The average beat rate of the operator during 30 min test duration was 107.2 beats per min, which was within the safe limits. The average oxygen consumption of the operator was 0.656 l/min. The physiological data indicated that operator was not physically loaded to get fatigued during the 30 min test period of operation of the decorticator. The above test data are presented in Figs. 10.14.

The numerical values of performance tests on decorticator are given in Table 10.1

The shelling performance values indicated that the shelling efficiency was high for the

Table 10.1. Performance of two manual groundnut decorticators developed at CIAE; Bhopal (*Source:* G. Singh, 1993)

Shoe clearance mm	Wire mesh grate decorticator			Decorticator with Slotted Grate		
	Shelling efficiency %	Breakage %	Capacity pods kg/h	Shelling efficiency %	Breakage %	Capacity pods kg/h
12	93.2	15.43	NR	NR	NR	NR
15	89.0	6.5	86	NR	NR	NR
18	88.2	6.10	85	83.97	12.63	60.6
20	88.4	5.13	80	82.63	8.47	59.54
22	83.2	3.70	70	84.0	8.4	54.30

wire mesh type grate. The wire mesh grate had also less of kernel damage as compared to slotted sieve and capacity was also more. The acceptable clearance for the variety under test was reported as 15mm and above. At high clearance the output and shelling efficiency are affected.

Manually operated rubber tyre sheller: The studies on shelling of pods have shown that rubber lined thresher cylinder cause less damage to the pods as compared to steel or wooden cylinder. Therefore a manually operated groundnut sheller was developed at Khon Kaen University in Thailand. The unit is shown in Fig.10.16. The size of machine is 580 mm (width), 1200 mm (length) and 1300 mm (height). The weight of machine is 58 kg. The machine consists of hopper, rubber tyre cylinder assembly, concave, mainframe, trough, bearings and top cover. The machine was able to shell 60-65 kg of pods per hour with shelling efficiency of 95 % and seed damage of 3-5 %. The machine is useful for shelling of pods for seed purpose and also for commercial use on small scale operation.

Power operated sheller (Fig. 10.17): The performance of power-operated machine was studied at six speeds of the cylinder (50, 100, 150, 200, 250 and 300 rpm). The clearance was fixed at 10 mm. The variety was Tainan 9 having moisture content of 11.94% (w. b). The performance was measured in terms of shelling efficiency, capacity and seed breakage (Fig. 10.18). The seed damage gradually increases from low value of 3 % to higher level

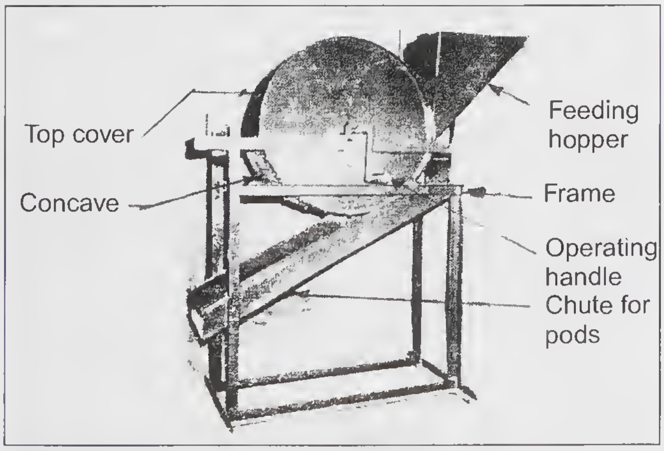


Fig. 10.16. Manually operated tyre type groundnut pod decorticator- Thailand model.

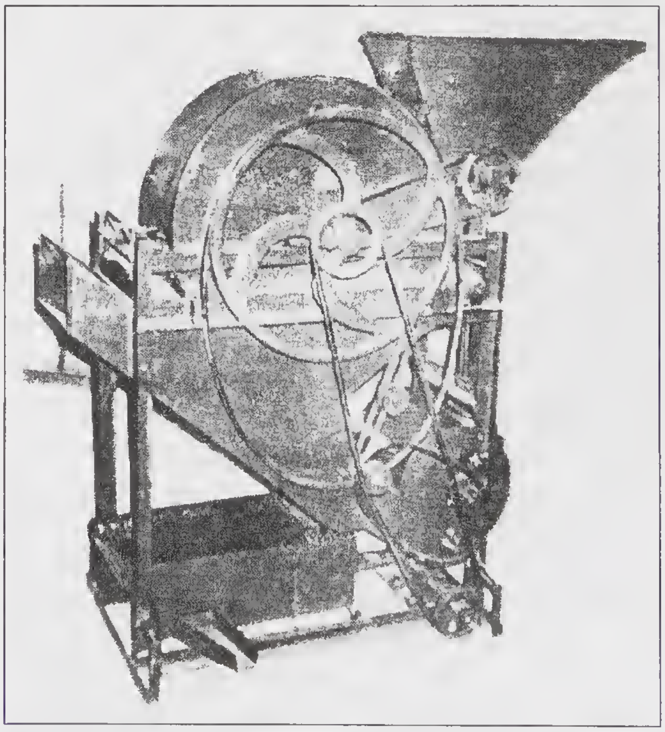


Fig. 10.17. Power operated rubber tyre type pod sheller- Thailand model.

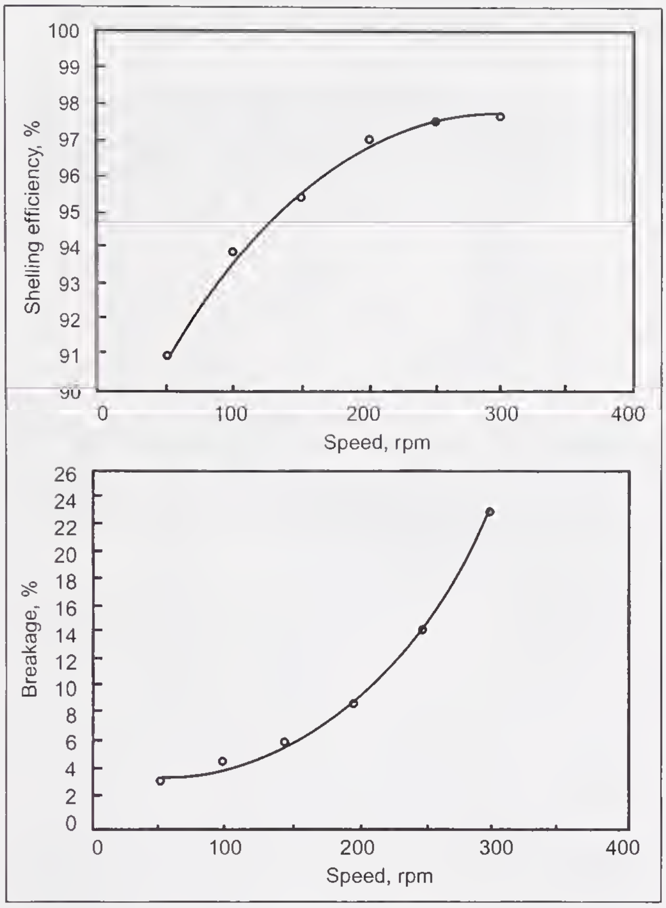


Fig. 10.18. Performance curves of power operated sheller showing effect on shelling efficiency and seed breakage.

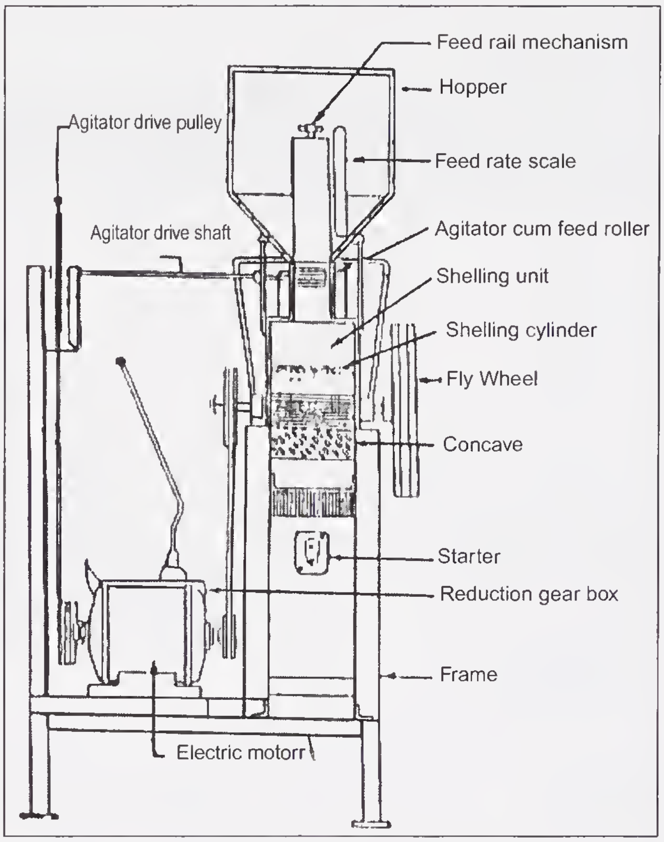


Fig. 10.19. Experimental machine developed for shelling of pods at PAU, Ludhiana.

as the speed increased above 200 rpm. The air velocity of 9.15 mps was able to blow out the shells of pods and other light debris. Air velocity above 11 mps increased the kernel loss. The unit is powered by 2 hp electric motor. The maximum output of machine was reported as 500 kg/h at the cylinder speed of 200rpm, with shelling efficiency of 95% and breakage of 4–6%, and cleaning efficiency being of 99%.

Groundnut shelling studies (Fig. 10.19, 10.20)

Chauhan *et al.* studied the performance of mechanical decorticators of groundnut pods. The parameters considered were operating conditions such as cylinder speeds (four), concave clearances (3) and feed rates (2) their effect on crop. The crop parameters taken in account were moisture contents (2) of one variety PG 1. The performance of machine was measured in terms of seed damage and shelling efficiency.

In this study the manually operated groundnut decorticator was modified as power operated unit with provision for changing the feed rate, cylinder speed and concave clearance. To minimize seed damage the three cylinders having shelling surfaces of rubber, wood and mild steel were selected. The concave was made from mild steel sheet with elliptical slots of 1x2.2 cm. The three concave clearances were 1.3, 1.9, 2.5 cm. The feed rates were 35 and 59 kg/h. The cylinder speeds were 3.29,5.5, 7.69, 10.11 mps. The moisture content of pods were 8.56 and 4.32%.

The results indicated that minimum damage for the rubberized cylinder was as follows:

- The seed damage is low when clearance is more but the shelling efficiency was also low.

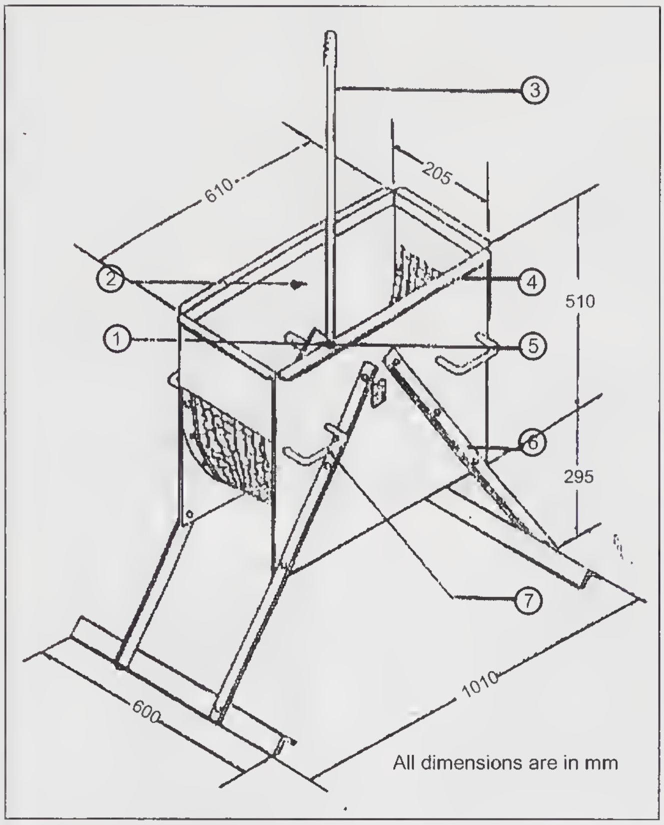


Fig. 10.20. Manually operated shoe type pod decorticator, 1, axle; 2, handle rod; 3, handle; 4, side frame; 5, decorticator shoes; 6, main frame angles; and 7, lifting handles.

- The increase in speed of operation for rubberized cylinder resulted in low amount of unshelled pods and low damage.
- The feed rate affects the pod damage and shelling efficiency. The per cent of unshelled pods increased with increase in feed rate.
- The seed damage was less at 8% moisture content as compared to 4.32%.

Singh and Thongsawatwong (1983) studied the performance of two peanut (groundnut) shellers. These were manually operated and the other unit was modified as the power operated unit. The aim was to identify the shellers suitable for the small producers and find the suitable crop and machine parameters for better performance and also for low seed damage during shelling operation.

The manual sheller was oscillating shoe type to be operated by two workers. It consisted of a box with bottom fitted with wire mesh type concave of 1x1 cm openings and a set of four shoes of size 5.8 x 22 cm with spike tooth type surface mounted on the frame and fitted with a long handle. The to and fro motion of handle moves the shoes over the concave and breaks the pods and pushes the shelled material out of the concave. The clearance between shoe surface and the wire mesh is 1.6 cm. The sheller box is filled with groundnut pods and then the unit is operated. The kernels and shells fall on the ground below the sheller. As soon as the level of pods goes down fresh pods are added and operation is continued. The test of two hour durations were conducted and the performance of sheller was reported as follows: the sheller capacity was 35 kg of seeds per hour with shelling efficiency of 97% and seed damage of 4.8%. The power unit consisted of the similar box type unit with wire mesh concave and shelling shoes operated by lever linkage system in a semi circular motion or oscillating type. The shelling is done by the similar action of rubbing/scratching of the pods between the shoe and concave as in case of manual sheller. In this machine the concave clearance was adjustable from 1.0 to 1.5 cm using spacer washers at the pivot point of rocking device. The unit was fitted with a feeding device and cleaning blower for removing the shells from the nuts. It was powered by an electric motor. During trials the blower, shelling and feeding units were powered by three electric motors. This was to study the power consumed in different operations. The feeding device was set for three feed rates with average values of 130, 180 and 280 kg pods /h. The shelling device was operated at the three shelling speeds of 92, 115, 140 strokes per minute. The three concave clearances were 1.0, 1.5, 2.0 cm. The sample size for shelling trial was 20 kg of pods for each test. The crop parameters were recorded. This included the dimensions

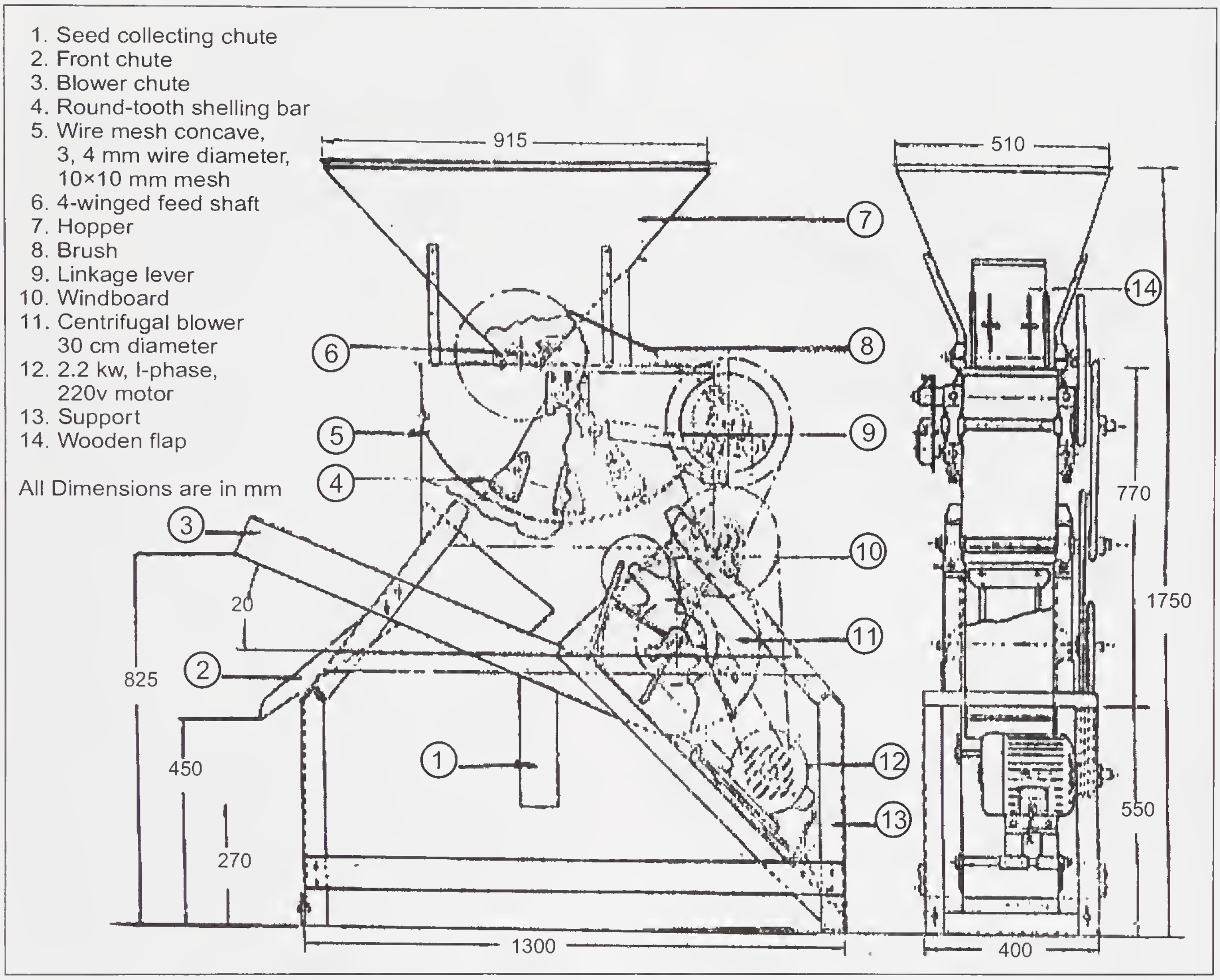


Fig. 10.21. Motorized groundnut (peanut) sheller developed at AIT, Bangkok.

of pods, per cent seed in pods and moisture content.

The average pod size was 2.6 cm length and 1.2 cm width. The seed content was 74%. The moisture content was 9%. For tests on varied moisture levels were for 10, 16 and 30%.The size of unshelled pods received was 1.6 cm length and 0.9 cm width. For blower and work performance tests, the length of pods was 2.7 cm and width 1.3 cm. With seed 72 % and 8.5 % moisture content, tests were performed to determine the shelling performance at different operating speeds, clearances and feed rates. The study showed that seed damage was affected by feed rate and clearance. At 1.0 cm clearance for the three test speeds the breakage was 20 % and it reduced to 8.5 when clearance was 1.5 cm and at 2.0 cm clearance the seed damage was around 5 %. Thus for power operated sheller the high clearance setting reduced breakage to 5 %. Thus for the power sheller high clearance setting reduced the seed breakage. Shelling efficiency was affected by the feed rate. The shelling efficiency was 98.7 % for all the feed rates at the shelling speed of 92 strokes per min. When the clearance was increased to 2.0 cm the shelling efficiency was the lowest at the three speeds of operation.

The shelling capacity of sheller increased

with increased feed rate. At shelling speed of 140 strokes per minute, the output of sheller increased from 93 to 123 to 172 kg/h respectively when feed rates were increased from 130 to 180 to 280 kg/h.

The best performance of AIT designed machine (Fig. 10.21) was achieved at speed of 140 strokes per min; 2 cm clearance and feeding rate of 289 kg/h. The performance of sheller was 96 % shelling capacity, 5% seed breakage output of 172-kg/h and power input of 0.9 kW. The power consumption increased rapidly as the sheller was overfed or over loaded.

When the groundnut pods were used for trials at high moisture level it was reported that the lowest breakage of pods of 2 % was reported at 2 cm clearance and at 16 % moisture content (db). The sheller performance was better when the pod moisture content was high i.e. at 16% but this advantage of machine would be available only when the shelled nuts are to be mechanical dried to safe level of 10 or below for safe storage to avoid spoilage. Normally the farmers do the shelling operation only after drying the pods in the sun to the moisture level of 8-10%. Thus it is concluded that for a power operated groundnut decorticator the design should incorporate a proper feeding device of suitable capacity to achieve energy efficient operation from the machine.

Commercial decorticators

A power operated groundnut decorticator manufactured by a firm requires 6 kW motor to shell 75 to 80 bags of groundnuts per hour(1,875 to 2,000 kg/h). The machine performs following functions: (i) feeding of ground nut pods to shelling unit; (ii) shelling of pods and separation of nuts from shells; and (iii) cleaning of nuts from shells.

The feeder mechanism consists of a hopper, feeder shaft, pawl and ratchet wheel to drive the shaft. The pods are fed to the machine at a uniform rate. The arrangement for changing the feed rate by adjusting the stroke length of pawl. The shelling unit consists of two parts, namely crushing plates and the grate. The crushing plates are made from close grained steel casting. Six channel grooves are mounted on the radial arms of main rotor shaft which is rotated at 110 rpm. As the main rotor shaft is operated the external grooved surfaces of the channels, roll and shell the pods. The crushing plates are mounted at an angle resulting in unequal gaps on both ends between the

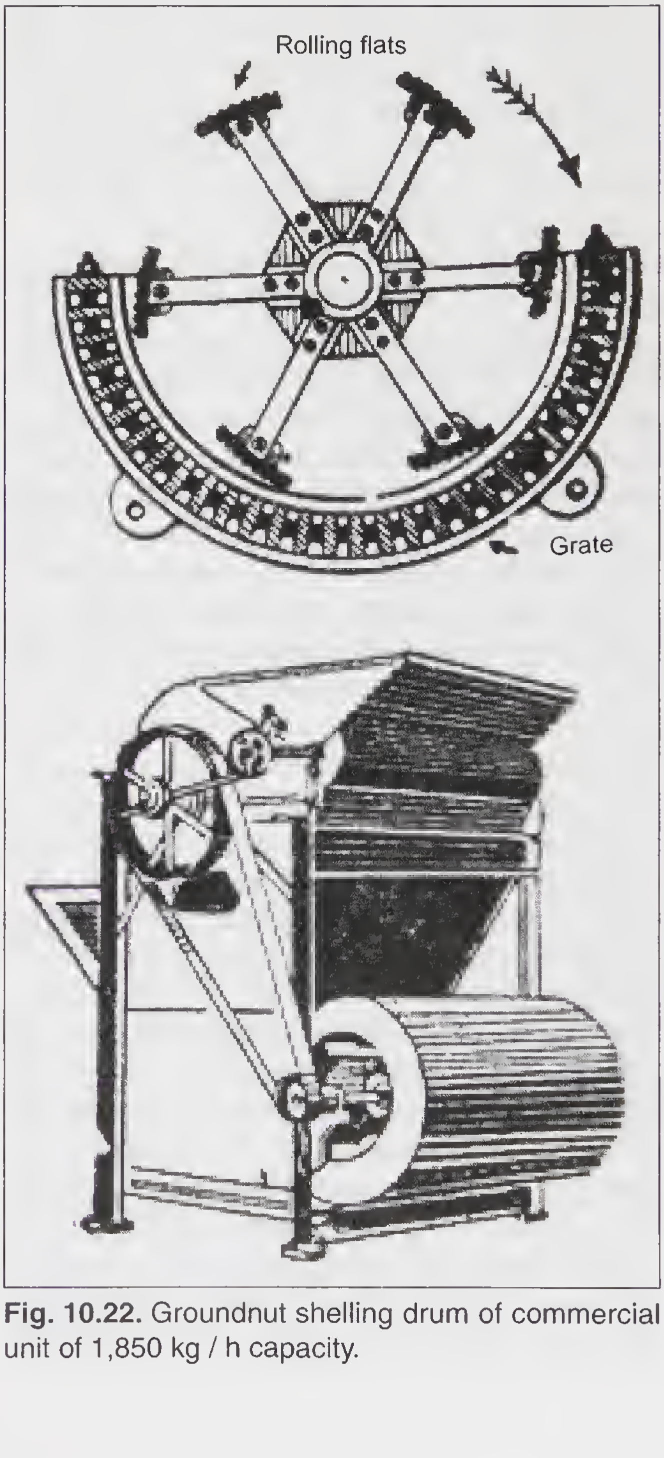


Fig. 10.22. Groundnut shelling drum of commercial unit of 1,850 kg / h capacity.

plates and the grate. The minimum uniform gap from 2.5 to 3.2 cm between the lower edge of the plates and inner surface of grate gives satisfactory performance. The grate is composed of a number of flat steel bars, placed horizontally on the edges with space between them which can be changed by changing the thickness of washers used between them. The fan is operated at a speed of 450 rpm by the main rotor shaft and is the basic part of cleaning section of the machine. The blower is made with four flat blades bolted to the four arms of angle iron fixed on the shaft. The blast of fan is strong enough to blow away the broken shells and the heavy nuts fall in the bottom pan due to gravity. The shelling unit is shown in Fig.10.22.

The studies and literature reviewed indicated that harvesting the groundnut at higher moisture level can help reducing losses, helps in achieving high performance from machines and reduce losses as well as seed breakage. The farmers prefer to harvest the crop when it is field dried to low levels. This not only increases the harvest losses but also the post-harvest losses. The efficient equipment for harvest and post-harvest operations are available and thus the losses can be reduced to half even in case of small-farm holders.

Threshing of sunflower crop

Farmers raise the sunflower crop, as it is hardy, short duration oilseed crop with high yield levels. It was popularized in the northwest plains of India but can be raised as spring season crop in other states in India. It can be sown after harvest of potato or cotton crops. The sunflower was introduced in India around 1980 as oilseed crop. During this time India was importing the large quantity of vegetable oil from the world markets. The Sunflower seeds were imported from Russia. The popular varieties were EC 68415-C and EC 69874. They had the potential of yielding up to 3.0 tonne/ha of sunflower seeds with oil content of 42%. The cultivation was taken up on large scale during 1985 in the states of Andhra Pradesh, Karnataka, Punjab and Maharashtra. This resulted in the need of threshing equipment by the farmers. The farmers harvest the flower heads and bring these to threshing floor for collection and drying in the sun. The number of manual tools and machines were developed and evaluated for the threshing of sunflower, which are described as small scale threshing devices. These were identified as

(a) For small quantities: Threshing Bench; Pedal operated Phule sunflower thresher; and Pedal operated UAS sunflower thresher.
(b) For medium capacity threshing of crops: Power operated Threshers; CIAE Multicrop thresher; Conventional spike tooth thresher; and Maize sheller for threshing sunflowers.
(c) For large scale threshing operations the farmers used: Sunflower thresher PAU design; APAU sunflower thresher; and Combine harvester in standing position.

Threshing bench: Threshing bench (Fig.10.23) consists of a rectangular or square frame of 300-400 mm size made of 25×25×3 mm angle iron frame the top of which is covered with expanded metal screen of 15 mm hole size. The height of frame is 130 mm. The worker has to rub the sunflower heads over the bench to remove the seeds in sitting posture. The seeds are easily detached from the flowers even at high moisture level of 30-34%. The output of the device is 3-4 kg/h. The cost of bench is low. This served the needs

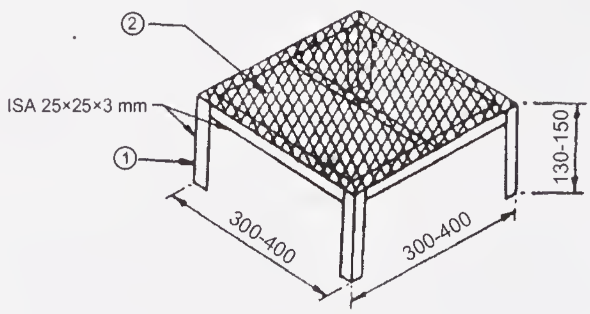


Fig. 10.23. Manually threshing of sunflowers using threshing bench.

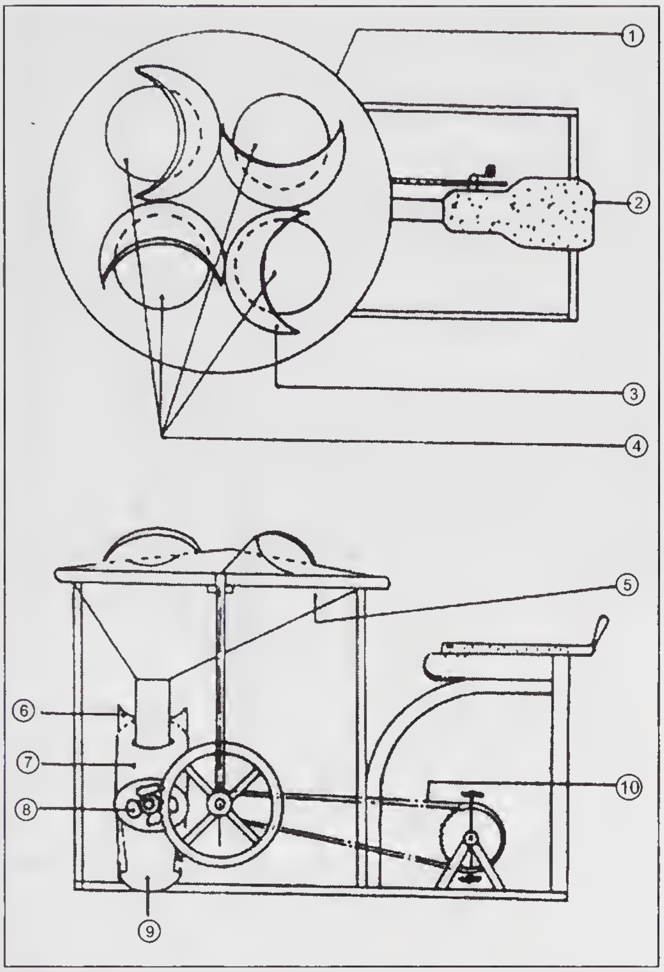


Fig. 10.24. Pedal operated Phule sunflower thresher. 1, Top cover; 2, Seat for operator; 3, Cap for inlet; 4, Feeding holes; 5, Seed collector; 6, Bhusa outlet; 7, Separation passage; 8, Fan; 9, Grain outlet; and 10, Power transmission by bicycle gear.

of farmers who raised the crop on a small scale.

The next development was the pedal operated sunflower threshers such as Phule sunflower thresher and UAS sunflower thresher developed at Rahuri and Bengaluru. These machines are shown in Figs. 10.24 and 10.25 respectively.

'Phule' thresher: The basic device used in threshing on 'Phule' machine (Fig. 10.24) is a bicycle wheel with spokes which the worker operates by pedaling at the speed of 150-160 rpm by means of bevel gear arrangement. The top of wheel is covered with sheet metal with four circular opening as inlets, which are partially covered with caps. The chain and sprocket drive used on bicycle transmits the power. As the wheel rotates in the horizontal plane and sunflowers with seed facing downwards are brought in contact with the wheel. The action of spokes helps in detaching the seeds from the flowers. The detached seed fall due to gravity at the base after they are subjected to air blast to remove the chaff and pithy material. A small fan rotating at 2,300 rpm provides the air blast. The output of machine was reported as 30-40 kg/h and two to four workers required for its operation. The threshing efficiency was 100% and cleaning efficiency in the range of 96-98% was reported.

UAS thresher: UAS machine consists of a rotating disc with number of pegs or spikes fixed on its surface. The disc is rotated by means of an up and down motion of the operator's foot. By crank and lever mechanism the disc is rotated at speed of 700-1000 rpm. The flower heads full of seeds facing disc are brought in contact with the disc surface where the action of pegs help in detachment of the seeds. Threshed seeds fall with some pithy matter below and are collected. The output of machine was reported as 25-30g/h per operator. The threshed material is cleaned separately by a cleaner. The machine is a modified version of a device normally used for sharpening the knives and scissors.

Power operated wheat thresher: The power operated wheat thresher 5 hp size was also tried for threshing of sunflower crop by making the changes in the cylinder speed. The speed of cylinder was reduced to 9-10 mps i.e. 350 rpm to prevent seed damage. The concave used was of 9 mm openings and clearance of 20 mm. The flower heads were fed in the machine. The output of machine was 80-100kg/h. The threshing efficiency was 99-100% and the cleaning efficiency was 60-70%. This was because of lower speed of blower. It was noticed that the pith of flowers was broken up in small pieces and it was passing through the sieves of cleaner shoe

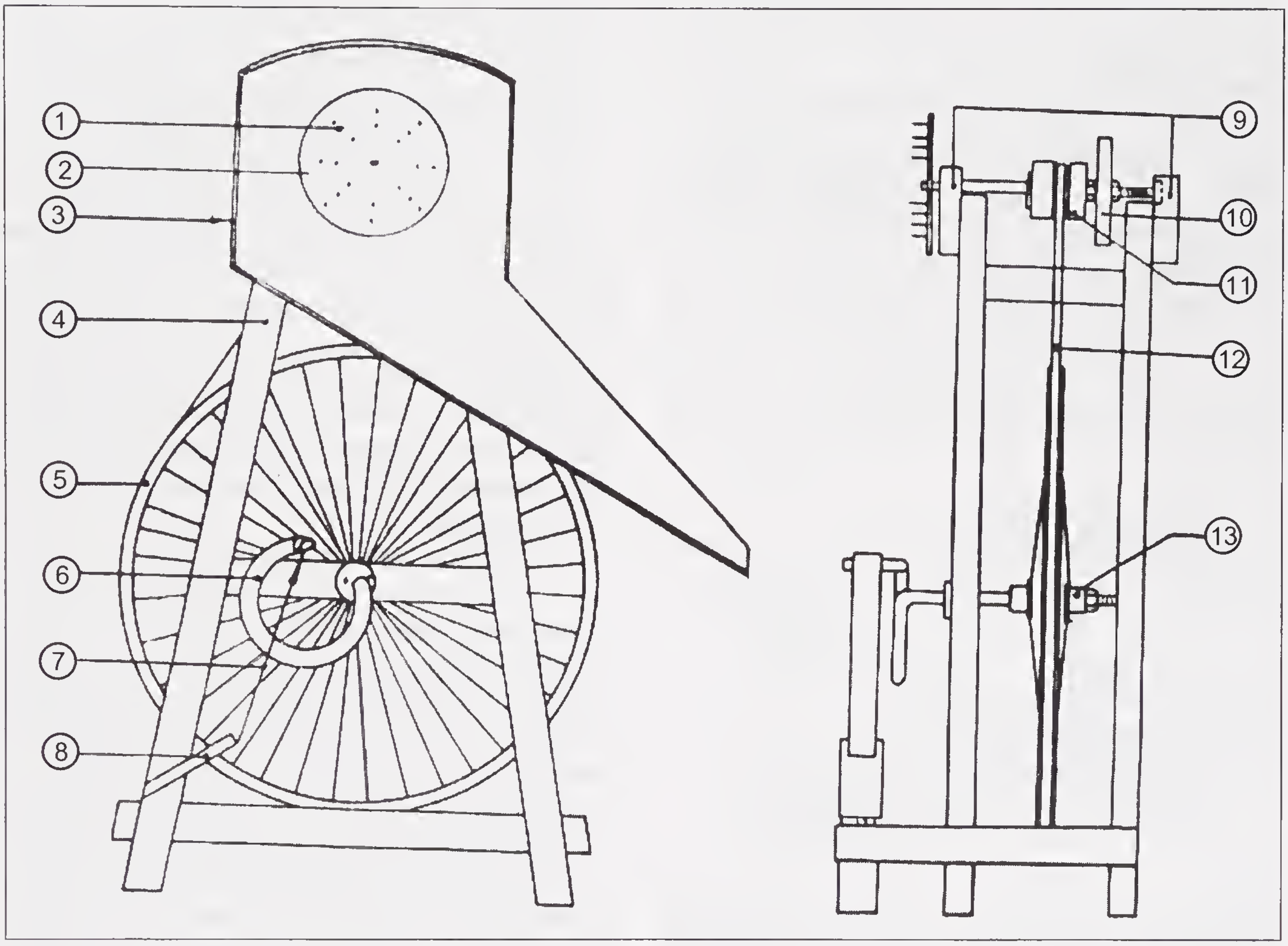


Fig. 10.25. Rotating disc type pedal operated sunflower thresher. 1, Disc spikes; 2, Disc; 3, Seed collector; 4, Frame; 5, cycle wheel; 6, Crank; 7, Lever; 8, Foot pedal; 9, bush bearings; 10, Flywheel; 11, Pulley; 12, Belt and 13, Hub.

resulting in a low cleaning efficiency. Drying the sunflower heads before threshing and winnowing the material can overcome this problem of low cleaning efficiency.

CIAE multicrop thresher: CIAE multicrop thresher (Fig.10.26) was evaluated for threshing sunflower heads during 1987. The thresher was set for operating at the speed of 350 rpm and the blower at the speed of 700 rpm. The concave had opening of 25 mm and concave clearance was 20 mm. At the feed rate of 440-540kg/h the output of machine was 165-239kg/h. The threshing efficiency was 100%. Cleaning efficiency was 92%. The seed damage was noted in the range of 2-3% and power consumption was 1.6-2.5 kw. It was possible to thresh sunflower at the moisture level of 22%. At this moisture level the thresher output was 79-101 kg/h. The low output of thresher is because of low bulk density of sunflower seeds. The bulk density of sunflower seeds was determined and was reported as 0.21g/cc.

Power operated maize sheller: The maize sheller (Fig.10.27) was successfully used during 1988 for threshing of sunflower heads. The shelling rotor is operated at the linear speed of 12mps for low rate of seed damage. The seed output of 600-900 kg/h was obtained when operated with a 35 hp tractor PTO pulley. As the cleaner blower speed was high it resulted in blower loss of 4.4% and

Fig. 10.26. CIAE multiple-crop thresher for threshing sunflower.

the cleaning efficiency was 92%. The shelled material is to be cleaned again with a cleaner to obtain the desired quality of product.

Power operated sunflower thresher: Earlier studies on threshing of sunflower by Shukla and Bal (1993) indicated sheller type machine had an output of 261 to 356 kg/h with 99-100% threshing efficiency and cleaning efficiency of 89-98% with blower losses of 0.22-.38%. The trials were conducted at drum speed of 6.51mps–10.23 mps. The performance of thresher was good at speed of 8.36 mps. The thresher was maize sheller type (Fig.10.27).

The maize sheller performance indicated that the sunflower could be threshed with 100% threshing efficiency. Therefore an attempt was made to design thresher of axial flow type with long cylinder of 1,050 mm length and 335 mm diameter with spikes of 50 mm size and sieve type concave with 11mm openings. The end portion of cylinder is extended to include the straw thrower of 4-blade type of 490 mm diameter, with thrower outlet opening of 95×100 mm. A blower with a single-screen cleaner unit of oscillating type was added to achieve better cleaning efficiency. The sieve was provided with 6 mm holes. The unit was to be operated by a 35 hp tractor for evaluation

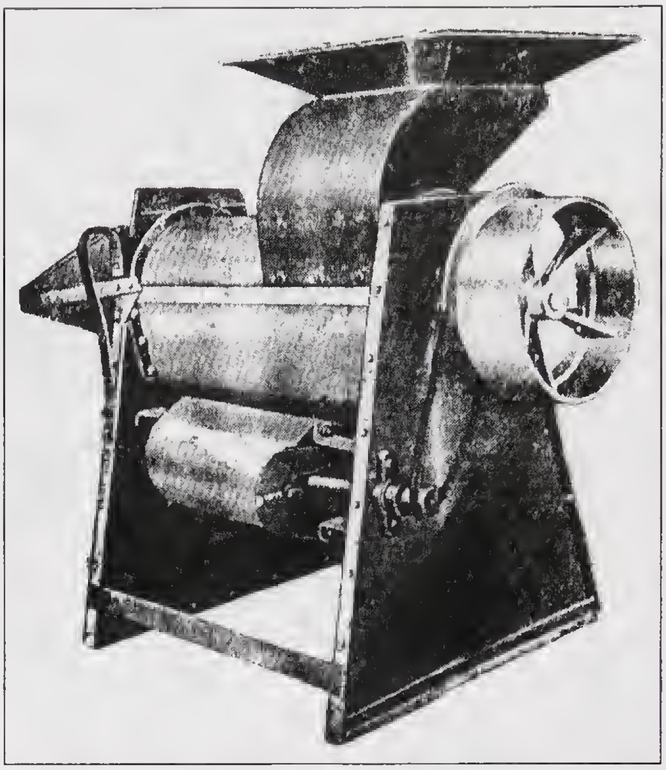


Fig. 10.27. Maize sheller used for threshing of sunflower head.

at Central state farm. The design was finalized taking into account the farmers are raising crops like paddy, maize and sunflower under the programme of crop diversification. The threshing cylinder with concave was of axial flow type with three distinct sections. The first section is feeding section, the middle section is the threshing and separation section and at the end is the straw throwing section. The thresher is shown in Fig.10.28. An axial flow thresher with helical flat bar type was also developed to be operated with 7.5 hp electric motor.

Combine harvester in stationery mode: The farmers having combine harvester (Fig. 10.29) can thresh the sunflowers after harvesting the flower heads of the crop in the standing mode. The flowers harvested are collected on the threshing floor. The threshing unit of the combine threshes the crop after disconnecting the power to header unit (cutter bar, gathering device). The speed of cylinder was lowered to 10 mps and the concave clearance is increased to 25 mm at front and 15 mm at rear. It was

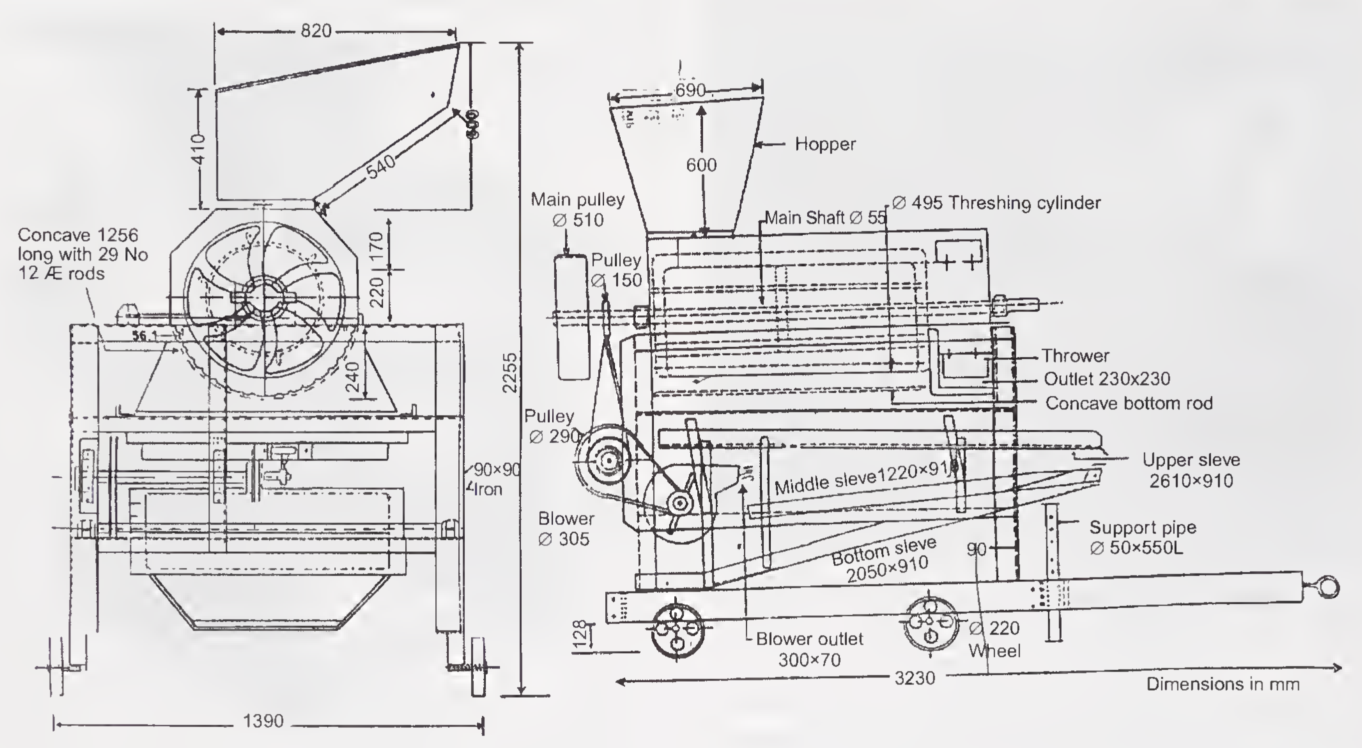


Fig. 10.28. “PAU” axial flow thresher for threshing of sunflower heads.

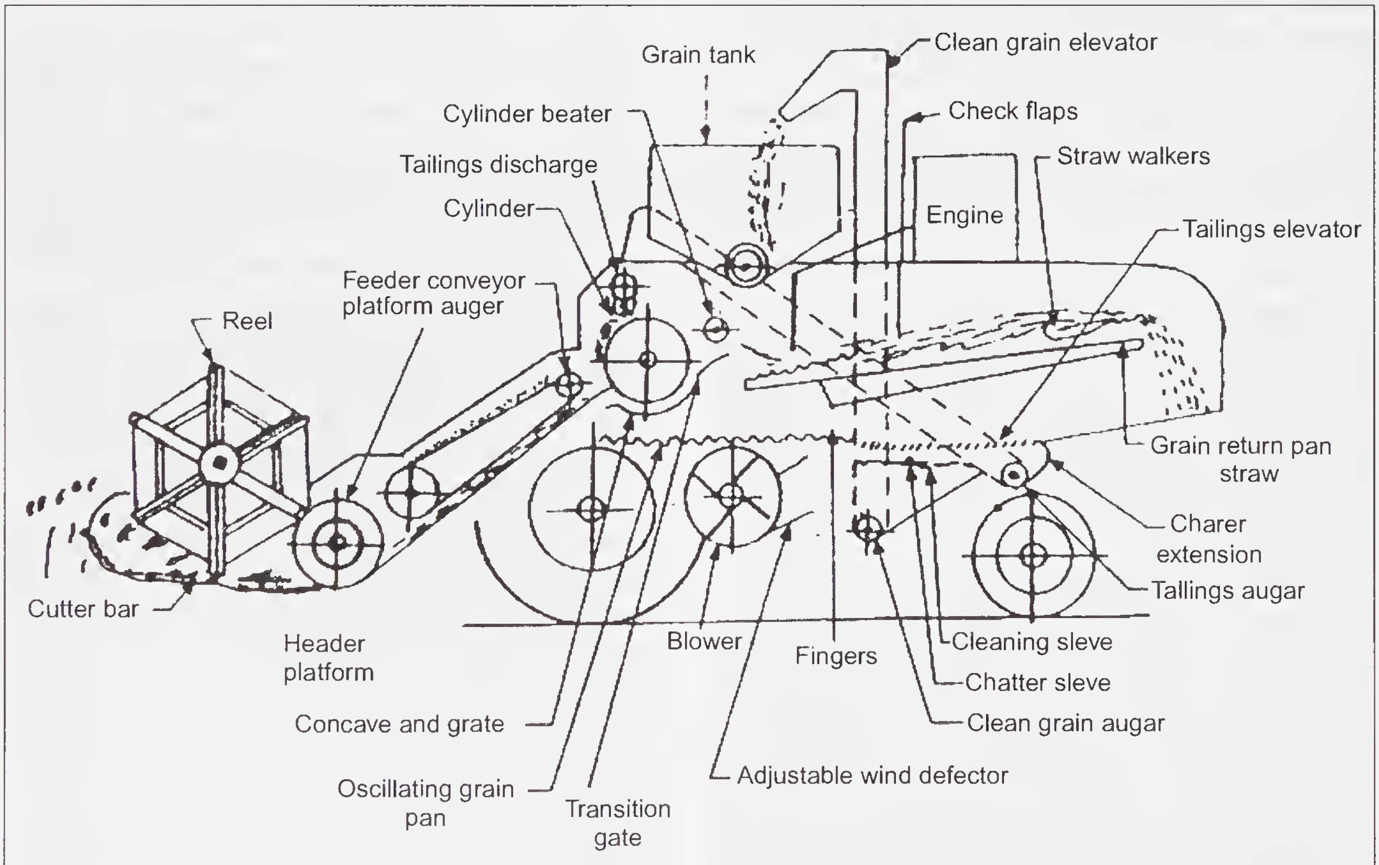


Fig. 10.29. Combine harvester used for threshing sunflower in standing mode.

Fig. 10.30. Sunflower thresher developed at APAU, Hyderabad.

reported that the threshing was good but the cleaning shoe required further adjustments. The cylinder speed need to be at 10mps to achieve high threshing efficiency from the machine.

APAU thresher: The research centre of Farm Implement and Machinery Project at Hyderabad developed a 5 hp size horsepower thresher for threshing of sunflower heads. It is based on axial flow threshing principles using a peg type cylinder with concave and two screen cleaning shoe. The field trials conducted at the centre and other locations reported the output of thresher as 135-200 kg/h with threshing efficiency of 99% and cleaning efficiency of 98%. The thresher is shown in Fig.10.30.

The sunflower seeds were used for expelling of oil in an oil expeller, it was noticed that the black husk of seeds affected the oil cake and oil colour. Thus it was desired to remove the husk before expelling oil from the seeds. Hence there was a need to shell the sunflower seeds prior to expelling.

Sunflower seed sheller—(TNAU type): The power operated sunflower seed sheller is based on centrifugal method of shelling the seeds. The sheller mainly consists of a rotor, a rubber lined stator, a blower and cleaning sieves. The graded seeds are fed into an elevating mechanism from where they enter into the rotor through the inlet chute of the rotor. The rotor throws the seeds on the stator and are shelled due to high impact force. The shelled seeds are subjected to air blast where the shells are blown away and the clean kernels are obtained. The unshelled kernels are separated for recirculation through the rotor. The capacity of the rotor of unit was reported as 125 kg/h when driven by 3.0 hp size motor. The machine required two workers to operate it. The unit is shown in Fig.10.31.

Thus it can be concluded that sunflower crop as raised by the farmers can be handled by the appropriate machines for threshing the flower heads in dry condition. The threshing is possible also at higher moisture level. Therefore crop is harvested at moisture level above 20% for higher yields. In areas where rice is raised followed by sunflower it is essential to have axial flow thresher suitable for both the crops.

The field losses for this crop are high as birds including parrots attack it in big way. The crop is generally grown in large areas owned by many farmers in the village. If the crop is sown in small area by one or two farmers in couple of plots, definitely the birds will damage the crop on maturity causing great loss to the growers. In all probability the birds will consume it even before it is harvested. The threshing devices described can be utilized to shell the flower heads successfully. The sunflower is having very high level of oil content and can be grown with small level of fertilizer application and one or two levels of irrigations. The yield levels are also good. The area under sunflower

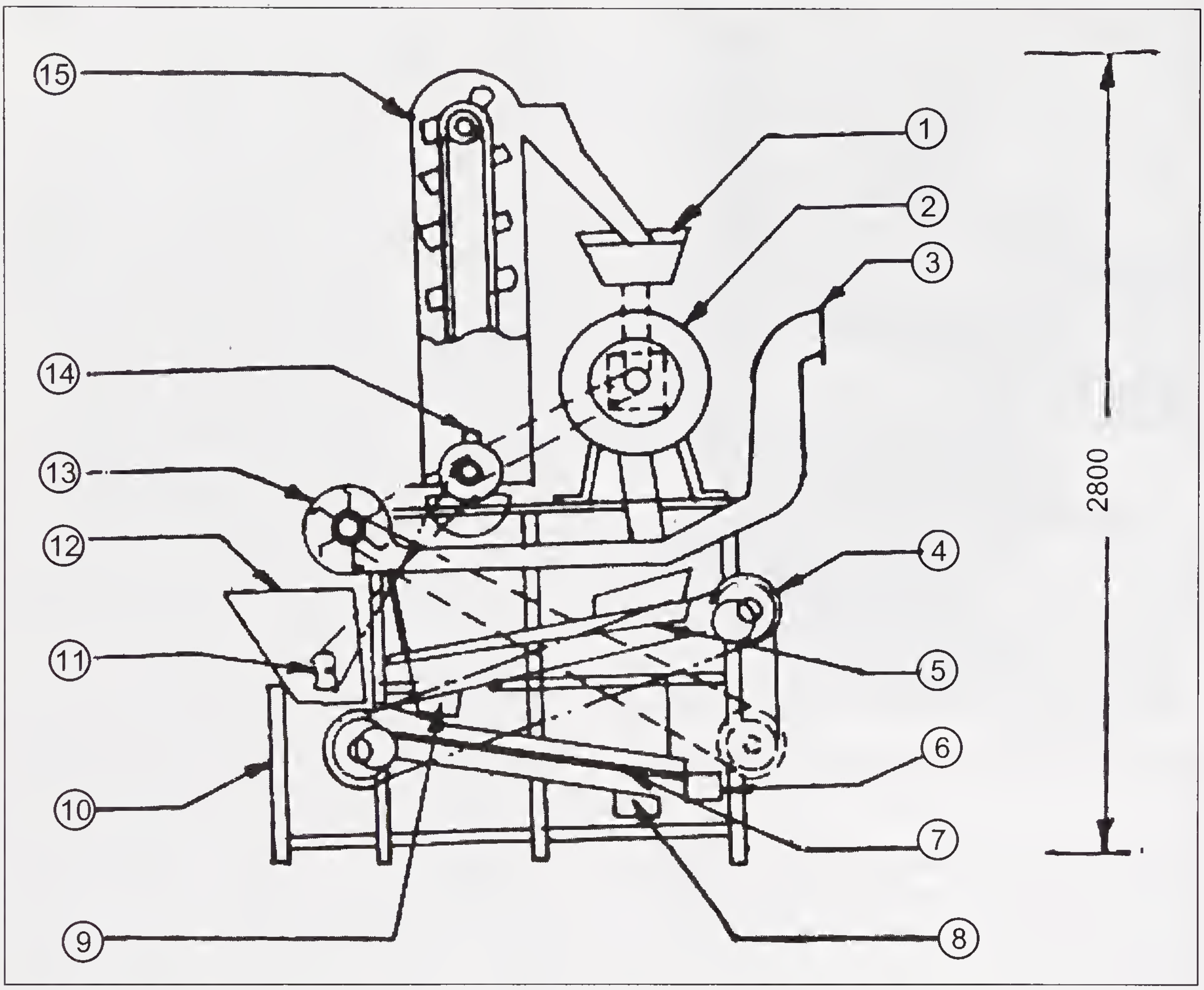


Fig. 10.31. Power operated centrifugal type sunflower seed sheller (TNAU design). 1, Hopper; 2, Shelling rotor; 3, Chute for husk; 4, Eccentric; 5, Sieve with 2.5mm slot ; 6, First graded seed ; 7, Sieve with 3.5 mm slot; 8, Grade ii) seed 9, Kernel; 10, Frame; 11, Feed roller; 12, Hopper; 13, Blower ; 14, Motor and 15, Bucket elevator.

crop has shown an increasing trend in the country. The consumption of sunflower oil has been increasing because of its low level of cholesterol producing properties.

Castor bean sheller/decorticator

Castor bean (*Ricinus communis*) is an important crop grown in Andhra Pradesh, Gujarat, Karnataka, Orissa and Tamil Nadu states of India. The area under castor crop in Gujarat state was reported as 175 thousand hectares in 1988. Castor bean is a valuable oil seed as the castor oil is used in manufacture of soap, varnish, hydraulic brake fluid, lubricating oil, perfumed hair oil. It is also used in textile industry and has medicinal use. Castor cake is used as a fertilizer for raising horticultural crops. Castor is grown as a rain-fed crop, as it is tolerant to drought conditions. The small farmers raise this crop by following indigenous agronomic practices but use the improved seeds to increase the production of the crop. The shelling and decorticating operations are important for the

farmers before he can sell the produce in the market. The looms are harvested manually and are sun dried before decorticating. The traditional method is to beat with a flail or by animal treading. To produce the quality beans the use of machines is recommended. The castor pod shellers have been developed at the state agricultural universities in the state of Andhra Pradesh, Gujarat and Tamil Nadu. The models developed are both the manual and power operated type units.

'APAU' castor pod sheller (manual) (Fig. 10.32): It consists of a wooden ribbed cylinder of 320 mm length and 380 mm in diameter,

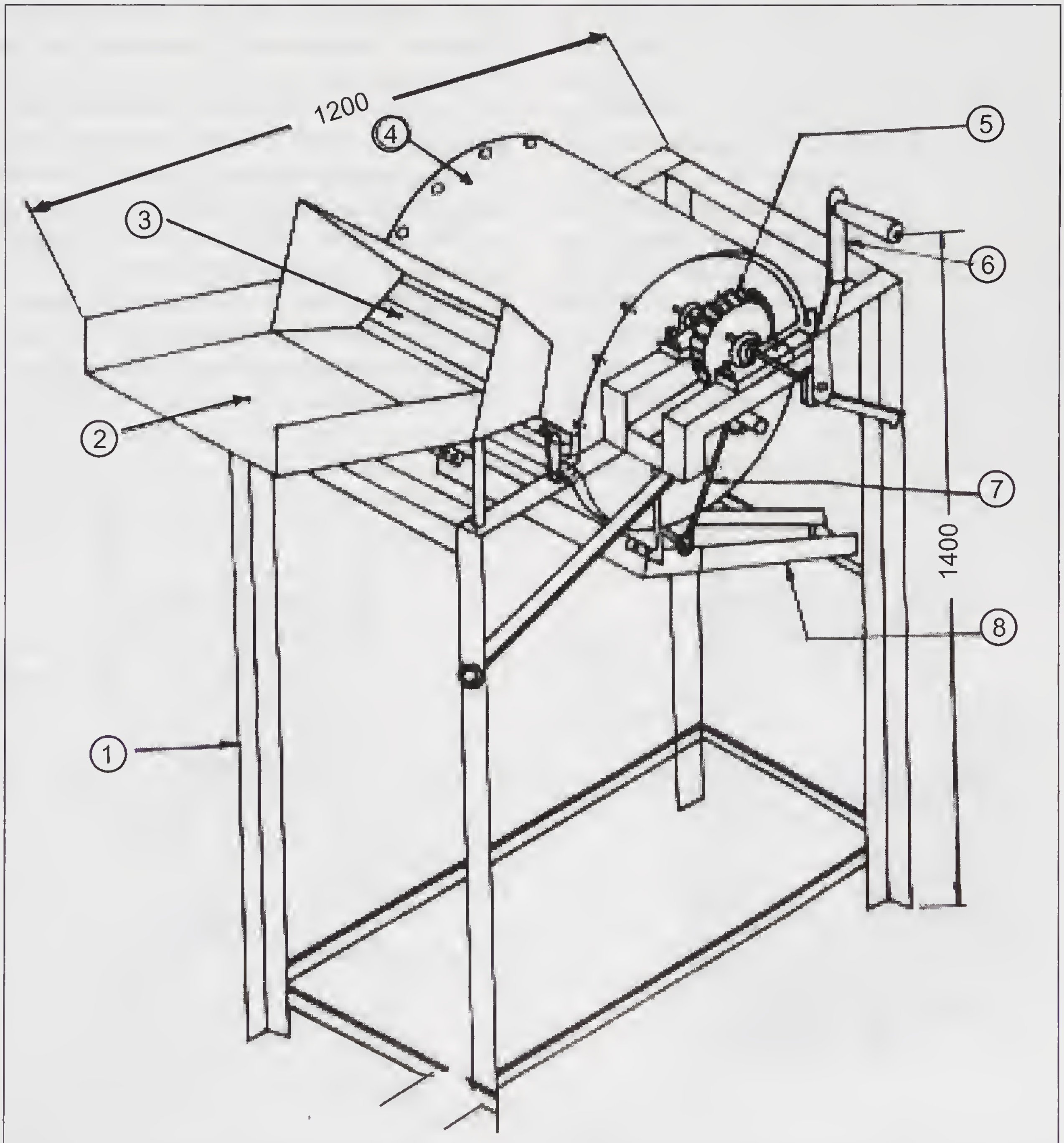


Fig. 10.32. Castor pod sheller manual type. 1, Frame; 2, Hopper; 3, Shelling roller; 4, drum; 5, gears; 6, Handle; 7, Crank and 8, Castor outlet.

concave, feeding chute, cylinder cover and shelled pod discharge chute. The concave clearance is adjustable according to the size of castor pods. The shelling drum is operated by a crank lever through a gear drive to increase the speed of the drum for shelling. The trial indicated that shelling efficiency of 97 % with kernel damage of 2 % was obtained at an output of 100 kg/h employing two workers on the unit. The unit is mounted on an angle iron frame and weighs 70 kg.

'APAU' power operated castor sheller (Fig. 10.33): It is similar in design to manual unit but as it being a powered unit is provided with the cleaning shoe with a blower. It is powered by 2.0 hp electric motor. The castor pods are fed into the threshing unit from the fed inlet where pods are shelled. The shelled pods, husk and unthreshed pods fall on the oscillating sieves. The unshelled pods fall out from the top of the sieve and collected for shelling. The middle sieve retains the partially shelled pods and allows the shelled beans to pass through it. The blower blows the hulls and chaff away. The shelled beans come out from the chute at the middle of bottom sieve. The bottom sieve allows the fines and dust including sand to fall on the floor. The trials indicated that the output of sheller was 250kg/h of pods.

'GAU' castor bean decorticator: It is a power-operated unit as shown in Fig.10.34. It consists of a rasp bar cylinder and a concave grate. The cylinder is operated at the peripheral speed of 207 m/min. The concave is made from sheet, which is having elliptical slots of 7 x 14 mm in size. The clearance for pod shelling is kept at 35 mm. for the minimum of kernel damage. For separation and cleaning two screens oscillating type cleaner is provided with a blower. The winnower type blower has the effective airflow rate of 1.0 cum per second. The sieves have the perforation of 8.27 and 6.25 mm diameter holes. The machine is operated with slope of sieves being 5 degree. The other critical dimension maintained are the stroke length of 37.8 mm and number of strokes were 270 strokes per min. The broken and fines are allowed to fall beneath the machine and clean pods are collected at main

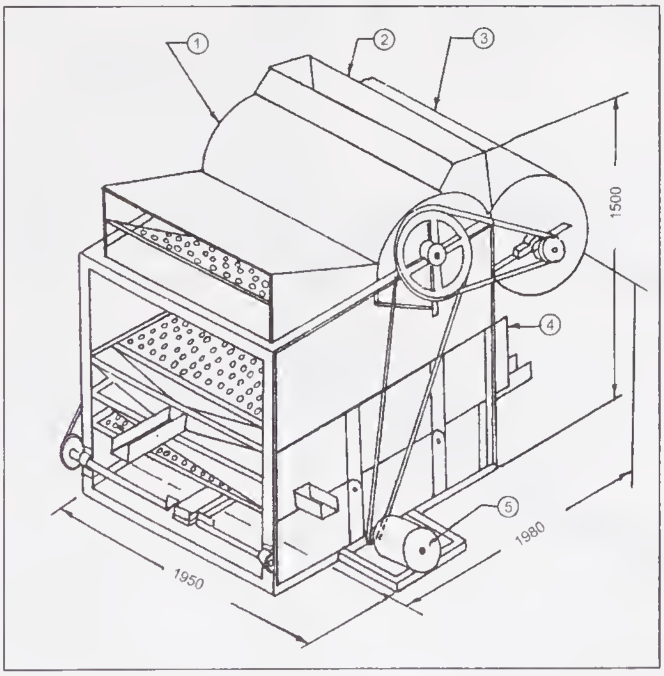


Fig. 10.33. 'APAU' power operated castor decorticator. 1, Cylinder cover; 2, Feeding hopper; 3, Blower Assembly; 4, sieve assembly; 5, Motor.

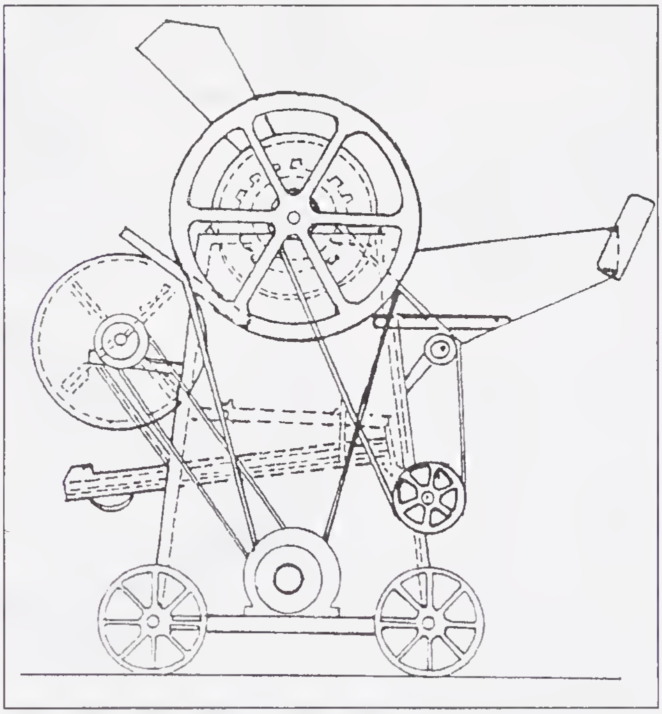


Fig. 10.34. 'GAU' power operated castor bean decorticator.

kernel outlet.

The performance of the decorticator was reported as follows:

1. Shelling capacity, kg/h 255.0
2. Shelling efficiency, % 97.33
3. Cleaning efficiency, % 98.41
4. Kernel damage % 0.28
5. Germination, % 83.0
6. Energy consumption, kw-h/tonne 8.90
7. Labour requirements, man-h/tonne15.0

'TNAU' castor bean sheller (manual type): The hand-operated sheller (Fig. 10.35A) consists of two wooden discs, which are covered with 6 mm thick rubber sheet on one side to provide a rubbing surface. The one disc is rigidly fixed to the frame and the other is mounted on the shaft and held against the stationary disc by means of a compression spring and the screw provided on it can adjust its tension. The clearance between discs is adjusted to accommodate different size of castor pods. The pods are fed into the shelling discs from the hopper fitted with a screw type auger to feed the material at the centre of the discs. A flywheel is provided on one end of the rotating disc and on the other end of shaft a gear drive is provided to increase the speed of the rotating disc. In manual sheller, the shelled material is allowed to fall below into the chute and by winnowing action it cleans the kernels. The trials with castor beans gave the following performance. The output was reported as 52.6 kg/h with shelling efficiency of 98.72 % and kernel breakage was only 0.88%. The output by manual rubbing of the pods resulted in kernel output of 11.7 kg/h.

The power operated castor pod sheller (Fig. 10.35B) is similar to manual machine in size and principle of operation. It is operated by a 0.5 hp size single-phase electric motor. The unit is fitted with a blower for removing the husk by the air blast from the kernels. The

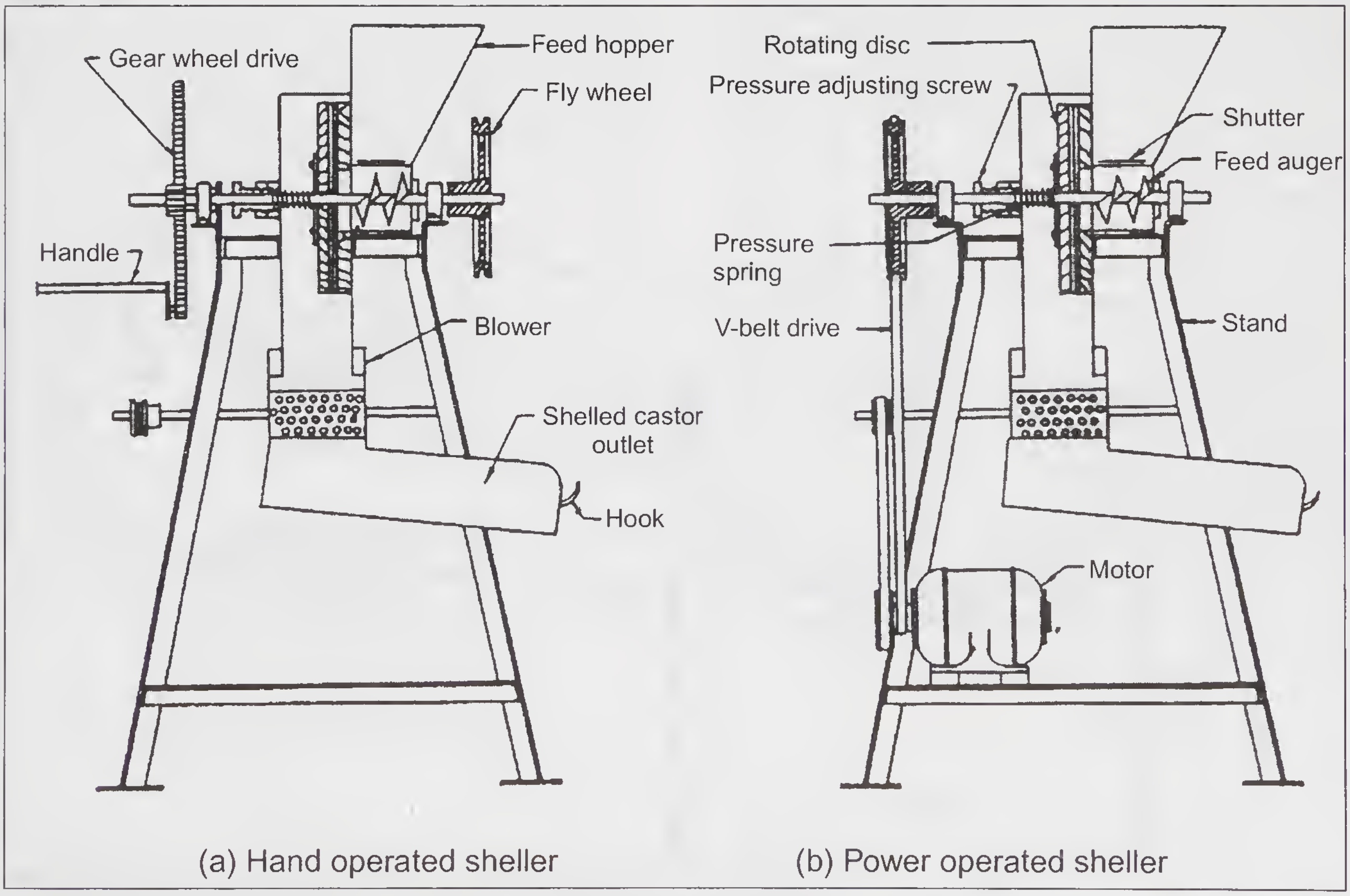


Fig. 10.35. 'TNAU' manual and power operated castor bean shellers.

shelling trials indicated the output of unit was 163 kg/h with shelling efficiency of 97.3 % and cleaning efficiency of 90.9 %.

Modified groundnut decorticator for castor pods

The manual oscillating shoe type groundnut decorticator was modified for decorticating the castor pods. The modification was made in the perforation size of the sieve. The sieve of 20 × 6 mm slots was installed and the clearance between the oscillating shoes and the sieve was adjusted to suit the size of kernels.

The trials on the unit indicated that the output of the unit was 76 kg of pods per hour with shelling efficiency of 95 % and breakage was less than 1 %. The unit is shown in Fig.10.36.The economic analysis performed at TNAU Coimbatore indicated that the manual decorticator can be used for decorticating 10-12 tonnes of material per year and power operated unit may be recommended when 50 tonnes of material is to be processed per year. In case the farmers grow groundnut and the castor crops one manual unit would serve the purpose for a few farmers provided they cooperate in using machine in turn as per their convenience and work schedule fixed by them.

Threshing of mustard, safflower and linseed

Threshing of other oilseed crops like

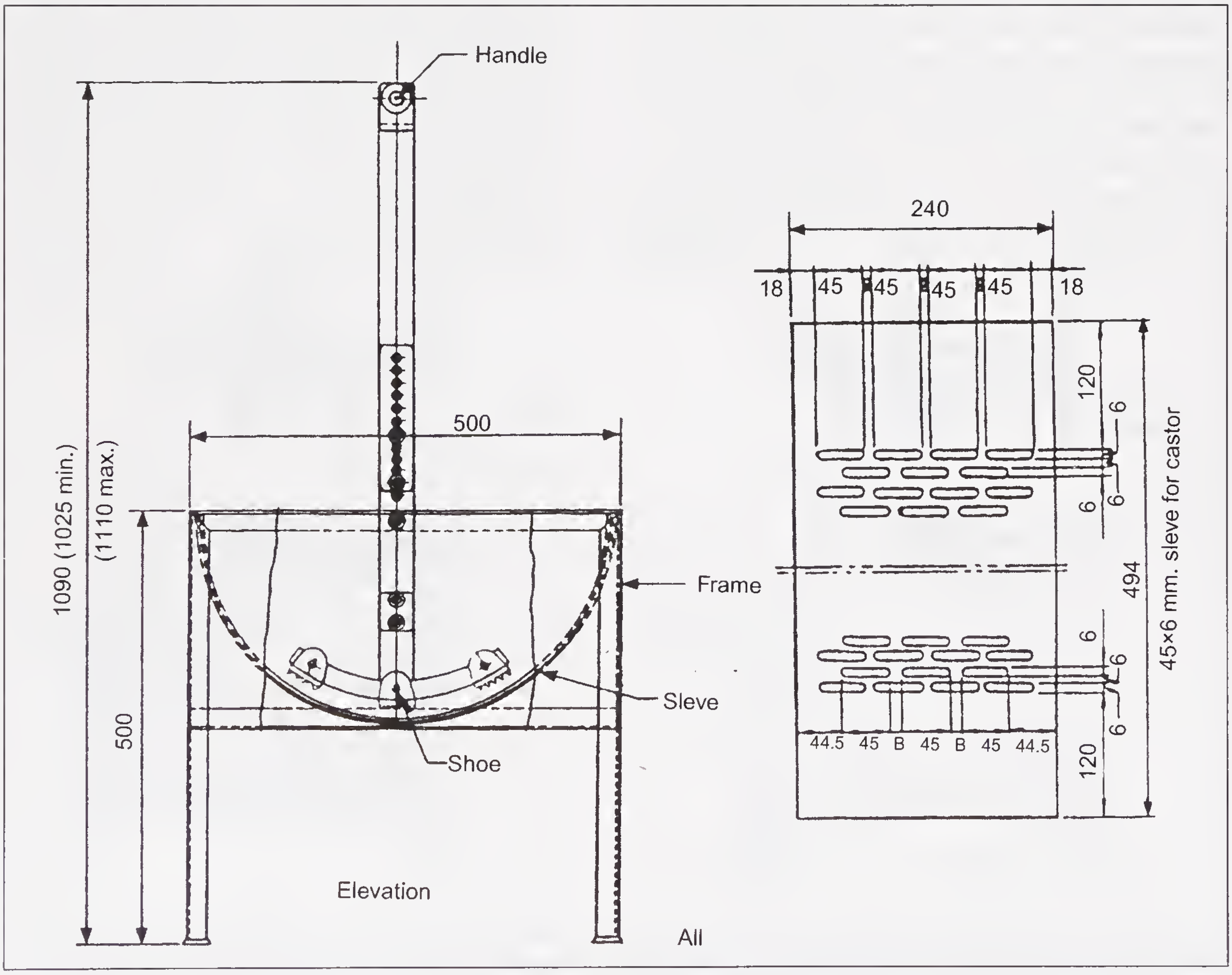


Fig. 10.36. Modified groundnut decorticator for castor pods.

Table 10.2. Thresher settings for multicrop type thresher for threshing oilseed crops

Crop	Thresher setting			
	Cylinder speed m/s	Concave clearance (mm)	Concave gap between rods (mm)	Sieve hole size (mm)
Linseed	16	15-10	7	5
Safflower	11	20-15	7	8
Rapeseed mustard	9	15-10	7	5
Castor	5	20-15	9	9
Sunflower	11	25-20	25	8
Groundnut	9	35-40	50-75	18x45

The concave size is important when threshing at low speed.

mustard, rapeseed, safflower, linseed were done with the CIAE multicrop thresher (Table 10.2). The thresher was set as in case of threshing wheat crop. The top cover is semi circular and a disc is inserted in between cylinder and straw thrower. The entire plant material was fed into the threshing cylinder to thresh the crop completely. The cylinder speed was set at 14m/sec in case of mustard and safflower crops. In linseed, the speed was set at 17-18 m/sec. The 5 hp thresher was able to give an output of 82 kg of mustard, 73 kg of safflower and 164 kg/h of linseed and the throughput was 300, 357 and 353 kg respectively. The threshing efficiency was 99-100% for mustard and safflower. In linseed it was 94.2% . The losses were high in mustard as they were mostly as spilled grain because of its round shape. The broken grain for mustard was 2.29% in Pusa Bold variety. The performance for these crops was reported to be satisfactory.

The axial flow principle of threshing is desirable for threshing crop at high moisture content and easy to thresh crops. Mechanical feeding devices will be beneficial to increase the output of machine and reduce labour requirements.

In safflower the threshing is difficult as the plant and flowers are thorny. Hence manual handling is problem. The workers are provided with leather glows and are covered properly so that they are not affected by the plant material. The crop feeding rate may be low in the thresher thus resulting in low grain output. The threshing cylinder speed is set at 9–10 m/sec. The threshing efficiency achieved is above 99% as the crop is dry with moisture level below 7-8%. In linseed, the cylinder speed is set at 16-18 m/sec for efficient threshing the top sieves are to be set according to size of grain 4-5 mm hole size sieve would meet the requirements for the most of the crop varieties.

The oilseed crops can be threshed with the developed threshers and made available to the farmers in the country. The users should be trained to set the machine for the crop which is to be threshed for good performance.

❑

11 Extraction of Plant Fibres

Cotton	150
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Cotton

The cotton crop is grown in India over an area of 9 million hectares in northern, central and southern states. The production is approximately 2.7 million tonnes, which is about 14% of world production. It is grown mostly as rainfed crop, which is around 60%. India produces all the four species of cotton. Arboretum and Herbaceum varieties called as Desi (Local) 21%, Hirsutum (39%), Hybrid (40%), Barbadense and other varieties. In India the cotton crop is mostly picked by hand in normal situations. It is grown in other Asian countries. The fibres that grow from the seed coat are called lint. These fibres are the most valuable part of the plant. The seeds are valuable as they contain about 20% oil, which is useful for human consumption as well as industrial application. The cotton boll contains the lint and seed; each boll contains four or five clumps called locks, which contain the lint and seed (Fig.11.1). The seeds and lint are called the seed cotton. The yield of cotton crop can be as little as 300 kg/ha to as high as 2,000 kg/ha depending upon the crop production practices and varietal factors.

Traditionally the cotton is harvested manually or bolls are hand picked from the plants. An average worker can pick about 10-15 kg of seed cotton per day. The cotton bolls do not open up uniformly so the field is picked, two or three times at an interval of a week. The crop is dry during picking period. The cotton pickers are paid on daily wage basis or on the basis of seed cotton picked. After the cotton is picked, it is collected and transported into bags to local market where the cotton is sold to the traders. The next operation for the cotton

Fig. 11.1. Cotton boll ready for harvesting.

is called the ginning process in which the lint is removed from the seeds. It is reported that although the most of the cotton is handpicked in India, the traders always complain about the presence trash in the cotton received from the farmers.

Cotton cleaning

Normally the hand picked cotton should not contain trash. But due to various reasons the Indian cottons are found to be trashy. They contain the trash of plant origin such as leaf, stems, twigs, unopened bolls, infected bolls, sand, dust, stones, plastic and polythene films, jute fibres, cotton threads, human hairs, bird feathers, paper and leather pieces. Normally the jute bags are employed to transport cotton to market or from there to the ginning factory. The harvested crop is dumped on the unpaved ground for drying in the sun before it is processed. During this period the cotton picks up most of the dirt and dust.

Cleaning cot: The traditional and simplest method of cleaning is by placing the cotton harvested on cleaning cot (Fig.11.2). It is a steel frame fitted with steel strips fixed on the frame with clearance of 12 to 15 mm between them.

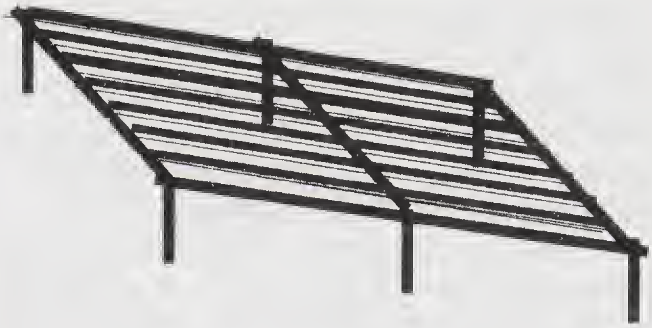

Fig. 11.2. Manually cot type cotton cleaner.

The cotton is spread on the cot and dust; sand smaller balls etc fall on the ground. The cotton is gently shuffled to remove the stems, leaves twigs, dust etc, including infested balls. Even after performing this process of cleaning some of the trash remains in the cotton. This method is practiced widely in southern states of India.

Drum cleaner: The cleaning of cotton by drum type cleaners is also practiced at many places. These devices are manually operated or fitted with electric motor. The cage type drum (Fig.11.3) is 1 to 1.4 m in diameter and is 2 to 4 m in length. The rods are fixed along the length of drum with 12 to 15 mm spacing along the cylindrical; surface forming a rotary cage. A few rods are joined together and are hinged to act as lid that can be opened to feed the cotton into the cage.

The end plates are perforated and a handle is provided for rotating the device. When the cylindrical drum rotates the sand dust, small bolls etc. fall on the ground and nearly clean

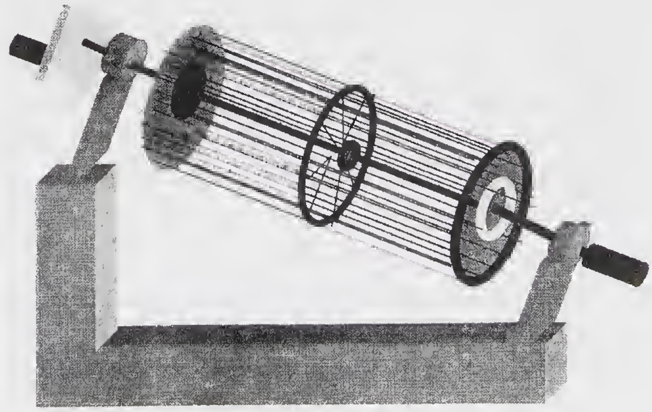

Fig. 11.3. Cage type seed cotton cleaner.

cotton is collected at the lower end. To remove bigger size defective balls these are to be removed by hand. The machine is manually operated and is very popular with ginners because of low wages of the operators who are employed to operate the machine.

Cotton cleaners (precleaners or extractors): The function of cleaner is mainly to remove coarse foreign matter, such as stems, burs, stones, immature locks, etc. The cleaning is achieved by the scrubbing action of spiked cylinders moving the trashy seed cotton over grid bars. The cleaning action is also achieved by centrifugal action on the trash entangled on the seed cotton and also by combing action of finger type cylinders. The extractors are designed to work or clean the machine picked cotton and is not recommended for the Indian situations where cotton is manually picked. These machines would be required when the mechanization of cotton harvesting would be introduced on a large scale in India.

Cylinder type precleaners: The precleaners used in ginnery are of multiple cylinder type and are either inclined or horizontal type. The inclined type precleaners are preferred because of the economy in space and ease in collection of trash. A schematic diagram of 5 cylinders precleaner is shown in Fig.11.4. The cylinders are with the spikes on them along their length with grid below them for collecting the trash. In some designs only longitudinal bars are used to agitate the cotton and to remove the trash and leafy matter from the harvested cotton. When the cylinder rotates, it opens the cotton and agitates it so that all the loose foreign matter is loosened. The rapid motion of the cylinders further tends to shake the foreign matter. The rotating cylinder also acts as fan and blows the foreign matter through the grate below them. The trash is collected and conveyed out of cleaner. The rotating cylinders move the cotton and deliever at the cleaner outlet. The machine can process 30 to 70 quintals of cotton per hour.

The need of precleaners among the ginners has been badly felt to produce clean cotton for export market in order to compete with foreign exporters/ traders. Due to such international pressure, about 15% of the industries have installed precleaners. Mostly the inclined cylinder type machine employing 3 to 6 cylinders operated by 7.5 to 15 hp motors are installed. The output of cylinder is about 1,000 kg/h. These units (Fig.11.4) are used along with roller gins.

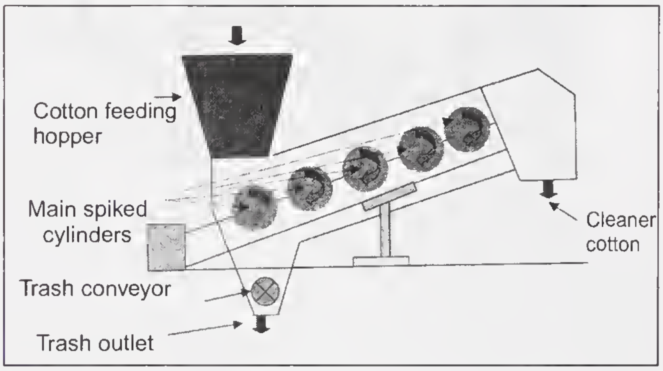

Fig. 11.4. Five cylinders inclined pre-cleaner.

Extractor type cleaners: The extracting type machines are basically saw band cleaners designed for removal of large foreign matter content such as limbs, stems and burs. The extractor cleaners are fitted with saw band cylinders, stripping rollers. There are doffing brushes present with saw band cylinder to doff seed cotton. The extractor cleaners are normally used after cylinder cleaners in ginnery since the extractor cleaner require well opened seed cotton for their optimum performance. The diameter of saw cylinder is in the range of 450-550 mm; and speed of rotation from 300-400 rpm. The doffing brush cylinder ranges from 250 to 350 mm., and speed is kept thrice the speed of saw cylinder. A single stage machine fitted with doffing brush developed at CTRI, Nagpur is shown in Fig.11.5.

Cotton ginning machines

In the ginning factory several machines are used before the actual operation of ginning. The machines consist of cleaners, driers, gin and pressing equipment. It is reported that the

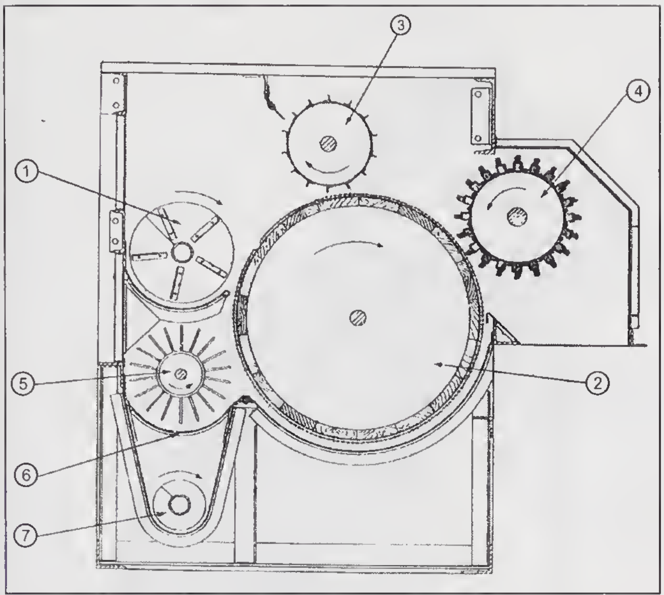

Fig. 11.5. An experimental extractor cleaner developed at Cotton Technology Research Institute, Nagpur, India. 1, Kicker conveyor; 2, Large saw cylinder; 3, Stripper roller; 4, Doffing brush; 5, Spiked conveyor; 6, Screen; 7, Trash conveyor.

trash in marketed cotton is estimated between 5 to 18%. It is the need of industry to reduce the trash in the cotton sold in local market to improve the quality of the cotton and thereby higher return in terms of monetary value. After the seed cotton is cleaned the next operation is the ginning operation where cotton lint is separated from seed.

Manual roller gin: The oldest gin is the small hand operated roller gin or charkha. The manual roller gin is shown in Fig. 11.6. It is used in villages in India even though its output is low. It is a device, which is simple and easy to operate.

Mechanical roller gin: The mechanical type roller gins are based on the principles developed in USA. The gin consists of a leather-clad roller, a stationary knife, mechanism to push cotton towards the fixed knife and a seed grid. A line diagram of section of single roller gin is shown in Fig.11.7.

The roller runs along the length of the fixed knife and is pressed against it. The moving knife reciprocates up and down between the fixed knife and a trough so that

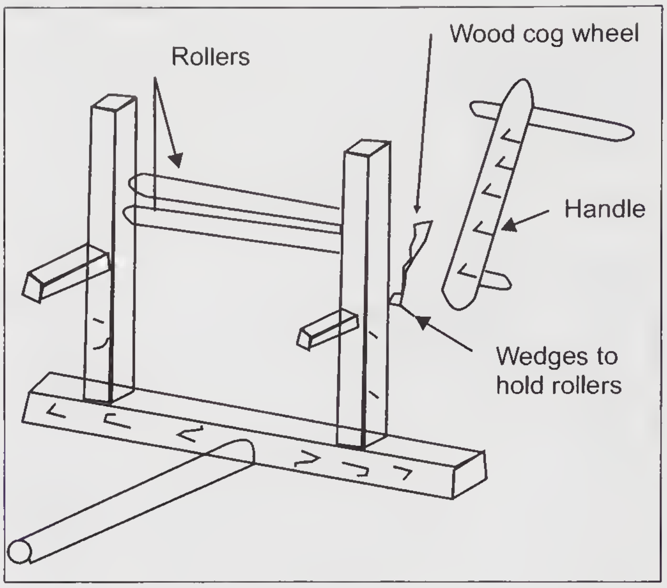

Fig. 11.6. Line diagram of roller gin manually operated in rural areas.

the roller surface is periodically exposed to cotton inside the trough. The fibres adhere to the surface of roller and as the roller rotates they are drawn between the roller and the stationary knife. Thus the seed gets ginned and the reciprocating knife pushes them. The extent of push is technically known as overlap and adjusted to the 1/3rd of the staple length of cotton being ginned for the optimum performance. The gins are provided with seed grid for removal of seeds as soon as the cotton is ginned. In a single roller gin the feeder and the reciprocating knife are separately driven. In double roller gins the trough oscillates symmetrically about the two fixed knife-edges at 1,000 rpm and on which are fixed two moving knives. Due to the speed of trough the cotton moves towards the rollers. For high ginning efficiency it is essential to have cotton close to the gin point that is along the length of the fixed knife. Auto feeder systems are nowadays fitted on double roller gins. This is an endless canvas belt moving at slow speed and running parallel to the side of trough. The cotton in the trough is carried to the gin point and thus the overall efficiency of machine is improved.

Overlap adjustment: The overlap is

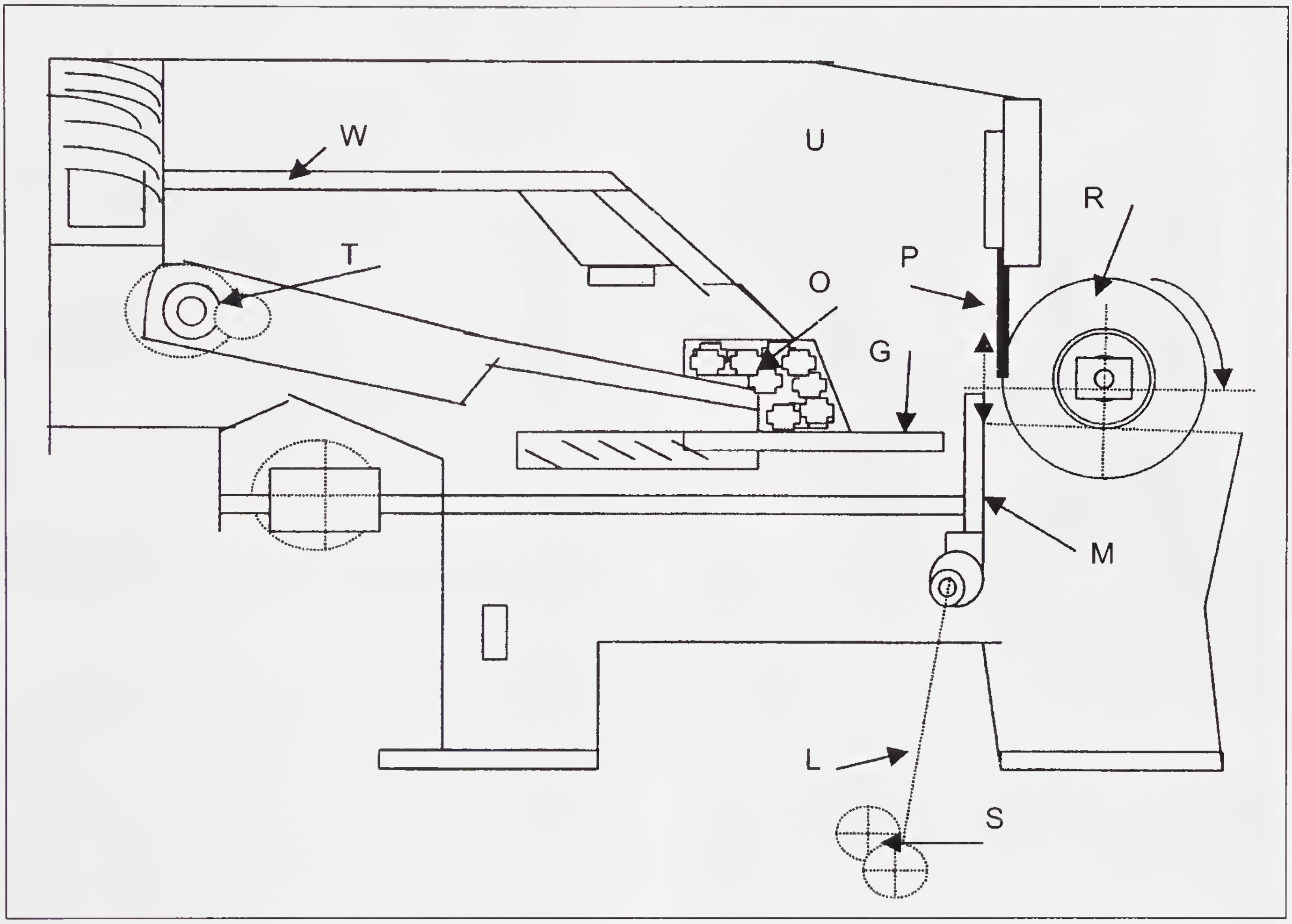

Fig. 11.7. Line diagram of power double roller gin. W, Apron; U, Trough; S and T, cranks; O, feeder bar; P, fixed knife; R, Roller; G, seed grid; and L, Crank leg.

adjusted by either controlling the amplitude of the moving knife or by raising or lowering the fixed knife in a single roller gin. In double roller gin this is accomplished with the aid of combination of an eccentric crank and a head pin connecting the crank to the beater shaft. In some machines the oscillating beater is designed to shift the moving knife-edges so that the overlap can be adjusted to the required value.

Rollers: The rollers are of 15.24 to 19.05 cm diameter and nearly a metre long. The speed of rollers is 110 rpm in double roller gin and 190 to 200 in single roller gin. The rollers are leather clad. They are mounted on roller bearings and are pressed against the fixed knife-edge. The pressure is in the range of 2.46 to 9.84 kg/cm^2. At present there is no technique to measure the pressure of knife on the roller. The pressure on the roller affects the surface temperature of the knife edge. When the pressure is high the cotton may even get scorched and the fibres may not be able to withstand the pressure and get damaged. Thus the cotton is processed at proper moisture level. In dry region the moisture is sprayed on the cotton and on the rollers to improve the ginning efficiency. In double roller gins, the rollers are mounted on swinging levers, using which the rollers can be pushed towards the knife-edges.

Saw gins: The saw gin is a multi functional machine. The saw gins (Fig. 11.8) are of two types, brush gin and air blast gin depending on the method used for the removal of the

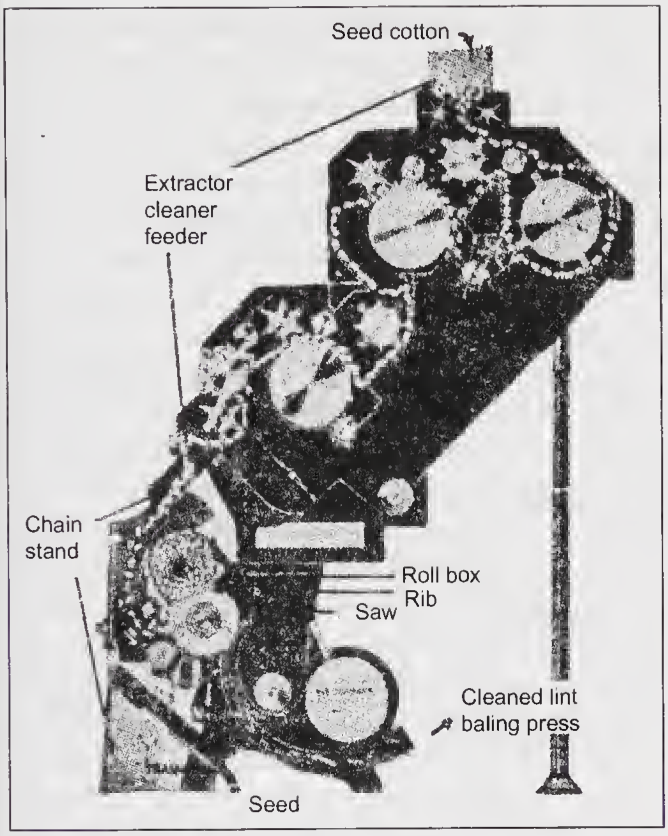

Fig. 11.8. Sectional view of saw gin.

ginned lint from saws.

The main parts of the saw gin are huller, picker rollers, steel ribs, saw, seed pan and collecting brushes. The gin saw is made of 0.8 mm thick steel plate and revolves at 650 to 700 rpm between two steel ribs spaced 3 mm apart. The diameter of saw varies between 25 and 39 cm. The saw have teeth with 9 teeth per cm. Due to rubbing action between picker wheel and screen, the seed cotton gets partially extracted and cleaned. The gin saw picks up the seed cotton with it and while passing through restricted space the lint is taken along and the seed is left on the ribs and it falls in the seed pan. The brush provided on the other side of rib picks up the lint. In some machines strong air suction is provided to pick up lint from the saw teeth. The lint is then sent for the cleaning and pressing section into bales. The capacity of saw gin varies from 4 to 5 kg per saw per hour. The quality of fibres gets affected due to tearing action of the teeth. There are from two to eight stands per gin and each is provided with 80 saws.

The clean cotton i.e. lint is baled into bales of 227 kg or 500 lb bales. For baling hydraulic presses are used. These are stationary type and standard equipment employed.

Jute

Jute is a very important fibre crop in India. It is grown in high rainfall areas of Bihar and West Bengal. The two types of jute grown are *Corchorus Capsularis* or *Corchorus olitorius*. A jute stalk at harvest is about 2-3 m high and about 6-10 mm in diameter. The stalks are manually harvested at the time of appearance of seed capsules. Workers harvest the crop with sickles about 3-5 cm above ground level. In case of submerged conditions the plants are uprooted and the roots are cut off later. The green crop of jute contains 5 to 6% of fibres. Thus green crop of 10 tonnes would yield jute fibre of 600 kg. The jute crop yield levels of 20 tonnes/ ha are achievable. The harvesting of jute crop is associated with the primary processing for the recovery of fibres. The fibres are located between the epidermis and central woody core of plants. The fibres, bark and woody core are detached from each other. The separation is achieved by immersing the stalks into the water for the period of 12–15 days. This process is called retting. The jute plants can be directly taken after harvest for the retting or sometimes stalks are dried before retting. The stalks numbering 50–100 are made in the bundle and are placed in the field ditches full of water. Weight is placed on the top of bundles to force stalks to remain under water. The fermentation process progresses slowly and in 10 –15 days the fibres can be separated from the stalks. The workers normally remove the fibres from the stalks by pulling with their hands and sometimes wooden hammer or stick is used to speed up the process. The separated fibres are washed in the water and are hung up on racks to dry in the sun. A worker can extract 3 –5 kg of fibres/h. Fig.11. 9 gives the view of field where

Fig. 11.9. Jute crop and its processing at farm level in a village of West Bengal, India

jute crop is raised and processed for fibre. The retting of jute stems can be speeded up either by chemical treatment, enzyme treatment and by the mechanical treatment of the stalks. The mechanical treatment is the easiest to be taken up by the farmers. In this process the plants are subjected to pressure in between the rollers to break the hard core and soften the epidermis. The machines developed at Jute Agricultural Research Institute, Barackpore and National Institute of Research on Jute and Allied Fibre Technology (NIRJAFT) Kolkata are called the Jute fibre extractor and Jute Decorticator respectively.

NIRJAFT decorticator/ ribboner: The machine (Fig.11.10) consists of a feeding, breaking, scrapping and delievery units. The jute stalks are fed into the machine at the feeding inlet and the steel rollers of fluted type pull them in. During the passage of plants from the rollers the hard core of the plant is broken and partially eliminated. The scraper unit removes the outer epidermis and to some extent cortex. Thus the ribbons are formed which have exposed plant material and when retted in water produces the good quality jute fibres and the period of retting is reduced. The machine is operated by one hp motor and can decorticate nine kg of jute sticks per hour. It is also suitable for handling Mesta crop. Two persons are required to operate the machine.

A Jute decorticator was also developed at Jute Agricultural Research Institute, Barackpore. The machine consists of a breaker unit and a scraper unit beside the feeding and delievery units. The pressure of fluted rollers breaks up the hard core of jute plant. The unit consists of three pairs of rollers and a scraper drum. The first roller breaks the jute stem, the second roller loosen the stock from the fibre and third roller holds the stocks and feeds into the scraping drum. The speed of rollers is 850 rpm and that of scraping drum is 200 rpm. Four to six plants are fed into the machine at a time and the fibres extracted are collected and subjected to retting for producing the quality fibres for commercial purpose. The machine is shown in Fig. 11.11. Tamil Nadu Agricultural University has also reported the design of jute fibre extractor and the design uses only two pairs of rollers for breaking and separating the stem pith. There is also

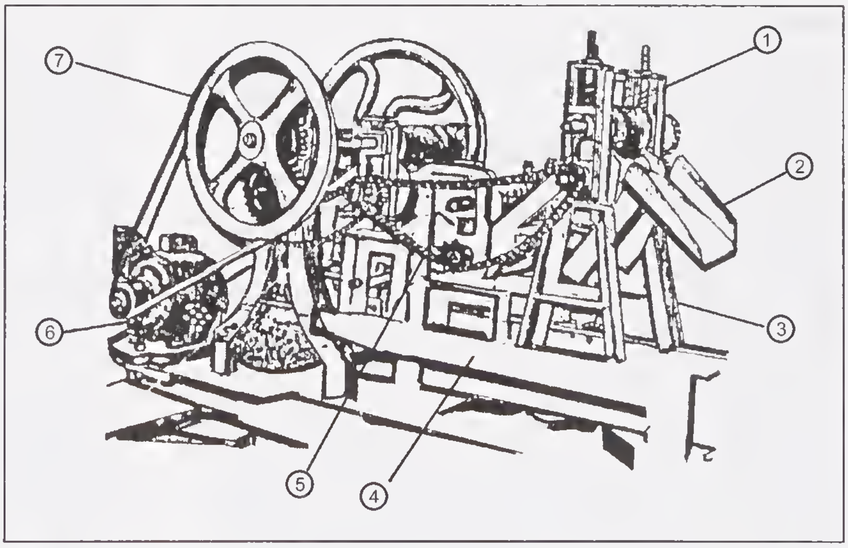

Fig. 11.10. Jute decorticator or ribboner (NIRJAFT design). 1, Extractor; 2, Outlet; 3, Stand; 4, Base; 5, Chain drive; 6, Motor and 7, Pulley.

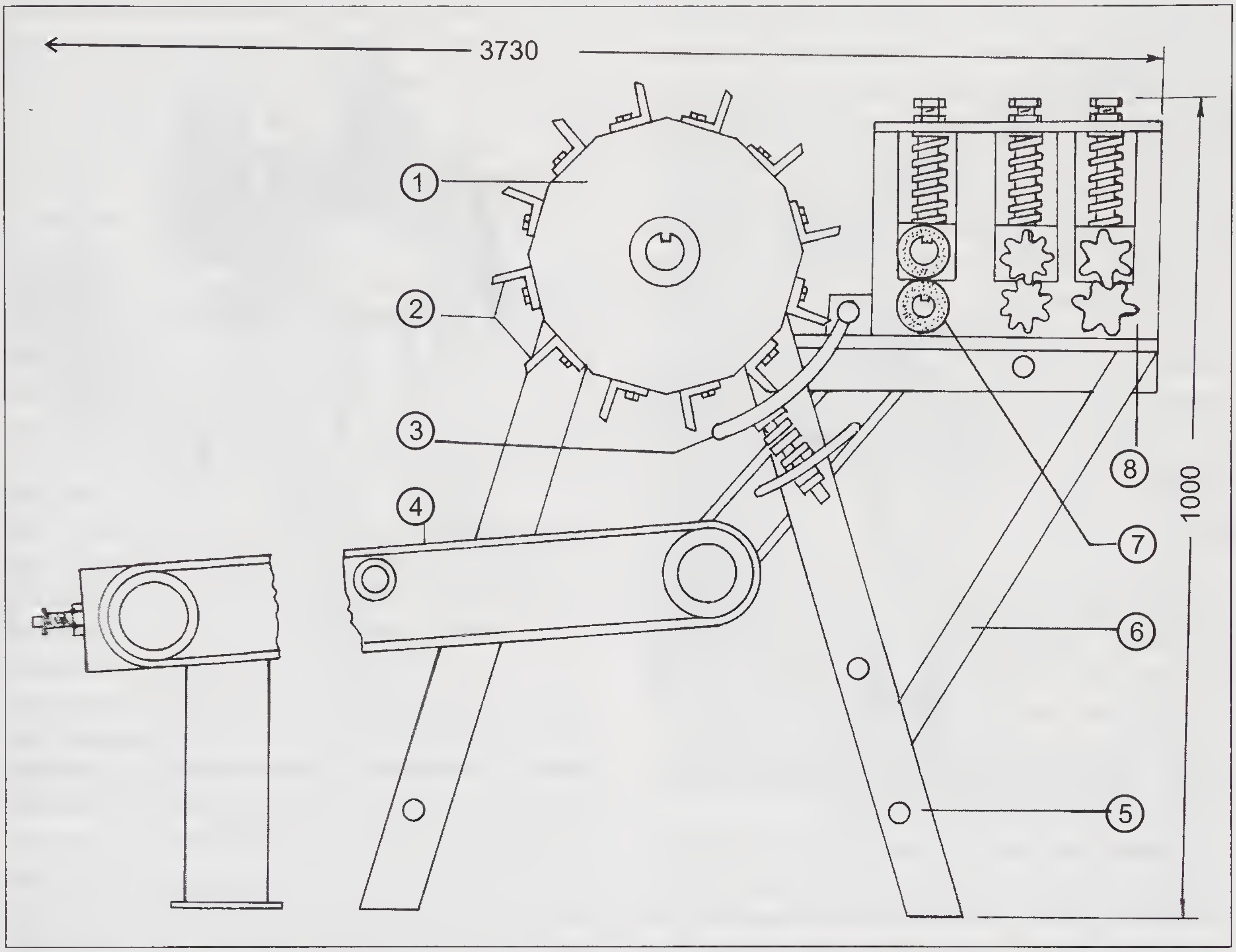

Fig. 11.11. JARI Jute fibre extractor. 1, Scraper drum; 2, Blade; 3, Counter blade assembly; 4, Delivery conveyer; 5, Frame; 6, Brace; 7, Rubber roller; 8, Breaker unit.

a scrapping drum at the end to remove the outer epidermis. The unit is powered by 2 hp motor and has output of 10 kg/h of dry fibres (200 kg of green stalks)

The use of decorticator gives the fibre ribbons of uniform size and, therefore, retting of the material is uniform through the length of plant and uniform fibres are produced. In case of traditional method the lower portion of plant is thick and with roots, therefore, it produces knotty fibre. The decortication also reduces time of retting by 5-6 days. The retting is also done by chemical treatment of plants or by growing fungus on the jute sticks and inoculating the jute plant stems for the extraction of fibre. In dry process the water requirements are reduced. The techniques have been developed at NIRJAFT, Kolkata and are being demonstrated on the farmers' fields. It was reported that good quality yarn was produced from the dry retted jute sticks. (*Source: NIRJAFT, Annual Report* 2004-05)

Kenaf (*Hibicus cannabinus* L.)

It is used as substitute for jute, but it is coarser and less supple. The kenaf is the annual crop with a single stem of 4 m length. The processing of kenaf is same as that for jute. The kenaf is the important crop of Sudan. It involves cutting, collection, decortications, fibre binding, retting, washing, spreading

for drying of fibres, refining and baling etc. Thus the total labour requirement for kenaf harvesting till fibre packaging is estimated as 154 man-days/ha. Thus for fresh crop output of 8-9 tonnes, required 154 man-days to produce 2.5 –3.0 tonnes of fibres. The harvesting of kenaf is difficult because of sharp spines on the stalks. The stalks are cut and collected for decortications. The decorticators described in Fig.11.11 are used for extraction of pithy matter. The decorticated material is then taken or transported for retting in the field ponds or ditches. After retting the fibres are washed and spread to dry in the sun before storage.

Flax

Flax (*Linum usitatissimum*) plant is fibre crop of temperate region, from which linen is produced. The fibres are located in the stem between the epidermis and central woody core. At harvest time the plant is 50-100 cm in height. In case of flax, the six unit operations involved are harvesting, deseeding, retting, drying, scutching and combing.

These operations are time consuming when done manually. The harvesting of crop manually takes 160-man-h/ha. Reapers can harvest the crop but due to cutting with cutter bar some fibre is lost in the stubbles left on the ground. Removing the seed bolls from stem is the process of deseeding. Pulling the plants through an upright steel comb called ripple the deseeding is achieved. The deseeding process of crop plants takes 18-20 man-h/tonne of crop. After deseeding the flax is rebundled into sheaves for retting. There are two retting processes. One is water retting and other one is the dew retting. In the dew retting the plants are exposed to dew during the early morning hours for long periods. In water retting the plants are kept into water tanks or water stream. In some cases the water temperature of 30-35 °C is maintained for the retting in the tanks. After the retting process, the flax straw is spread in the field for drying in the sun. The separation of fibres from the dried plant in case of flax is known as scutching. In case of flax the plant stem are thin and size is around 1 to 1.2 mm in diameter.

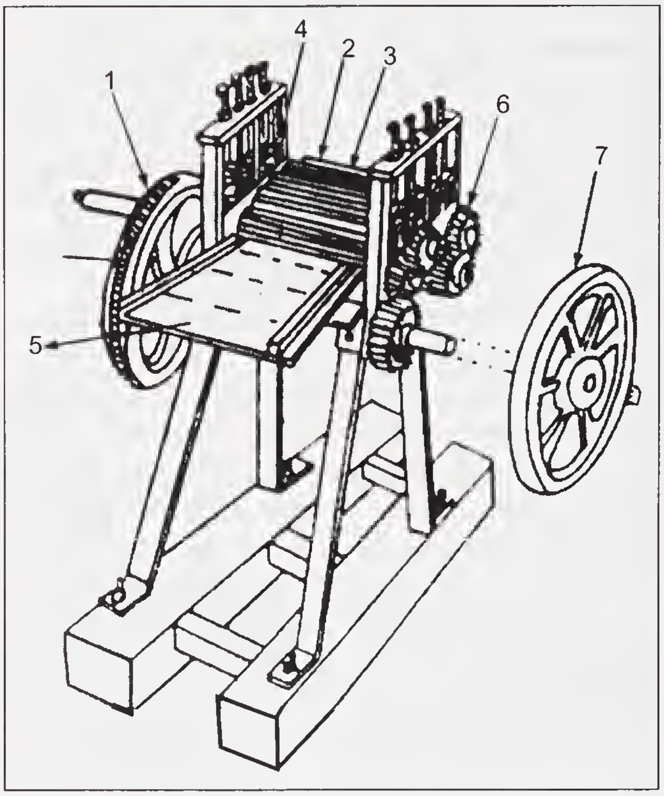

Fig. 11.12. Flax-scutching machine manually operated. (1), Handle; (2), fluted rollers; (3), pressure springs; (4), gears; (5), feeding tray; (6), gear for conveyor; and (7) second flywheel.

During scutching the stems are crushed and broken by passing through the series of fluted rollers. Beating and scrapping remove the dry pieces of stems from the fibres. Decorticator removes dry broken pieces of stem. The scutched fibres are then drawn over a series of combs. This operation removes tangled fibre and straightens long fibres and lays them in parallel strands. Thus flax fibres are produced. The details of manually operated flax scutching machine suitable for small farmers is given in Fig.11.12.

Coir

Coir is the fibre obtained from coconut husks. When coir is obtained from green coconuts, the fibres are white in colour and the ripened coconuts give the coir of brown colour.

The fibres are obtained from coconut husks by beating the husks. The first step is to dehusk the coconut to get the husk of the coconuts. It is reported that 40 coconuts yield about 2.7 kg of coir. The first step is to remove the husk from nuts by ramming the coconut onto the stationary spike and ripening the husk from the nut into 3-5 pieces. The husks are then retted for 1-6 months in fresh water or seawater to loosen the fibres.

The powered crushing rollers are used to crush the husk to speed up the retting process. After retting the fibre is dried in the sun. The dried husks are further treated with machine to remove the particles attached to the fibres. The machine consists of roller with spikes or needles, which strips particles from the coir fibres when held before the rotating drum, which is operated with foot treadle. The machine can produce 5 kg of fibre/hour. A power-operated machine can give 200-250 kg/h when operated by a team of three workers. The fibres can be produced using power-operated decorticators without retting. The fibres obtained are put through carding machine before being made into rope, twine, or mattress stuffing.

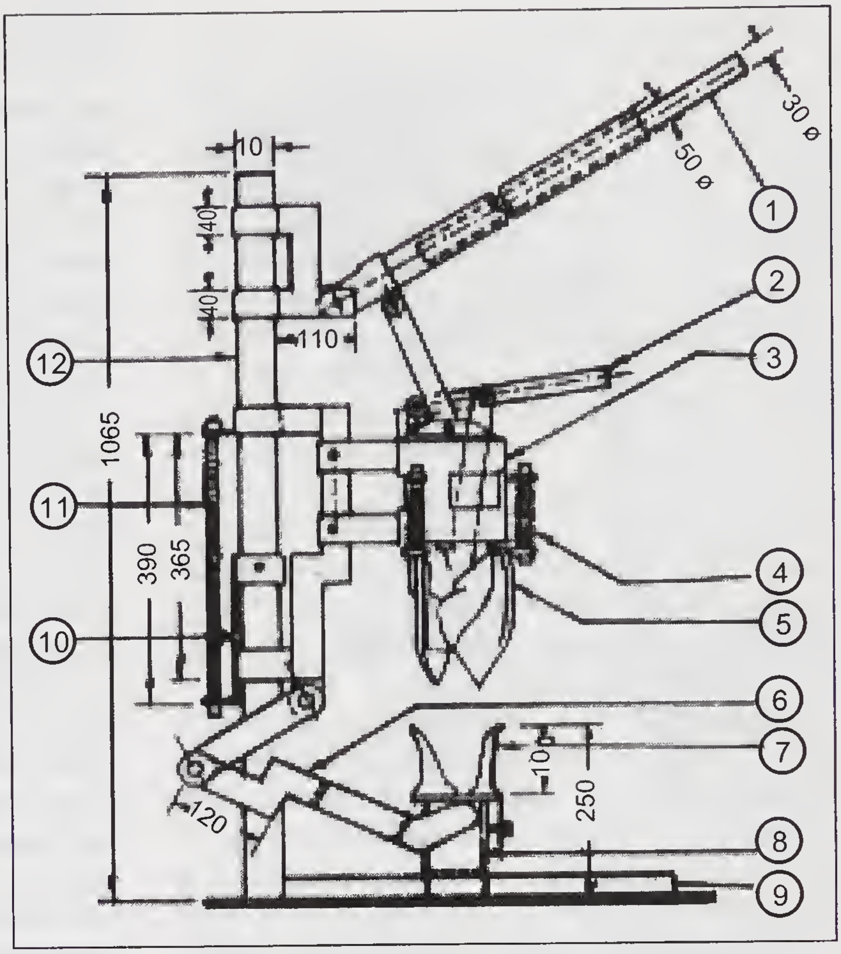

Fig. 11.13. Coconut dehusking machine manually operated. 1, Telescopic lever; 2, Lever with connecting rod; 3, Tool holder; 4, Blade spring; 5, Blade; 6, Platform blade; 7, Lever mechanism; 8, Base blades; 9, Platform; 10, Frame; 11, Return spring; 12, Vertical shaft.

Coconut Dehusker: For production of coir the coconuts are to be dehusked and nuts are separated. The traditional manual method uses the skilled operator who with a spear shaped spike fixed in the ground pushes the coconut on the spear point and by pushing and twisting action removes the husk from the nut. This is processed for production of coir. The Central Plantation Crop Research Institute at Kasargod, Kerala reported the development of machine for dehusking coconuts during 1986. The unit consists of a piercing blade assembly and the coconut holding base fitted with blades.

The coconut is placed on the base blades and the piercing blades are pushed downward by a long telescopic handle by the operator. The piercing blades are shaped in such away that when they come in contact with the nut they expand in the horizontal plane. Thus gives the husk a twist, which helps in detachment of husk. The unit is shown in Fig.11.13. The output of unit is 150 nuts /h/ worker operation. Though a skilled worker with traditional tool can dehusk more nuts but such skilful workers are not available and hence the unit is useful for use by any farm worker.

Sisal (*Agave sisalana*)

The sisal (*Agave sisalana*) fibres are used to make twine or rope, which is mostly used in tying of the hay bales for use in balers and reaper binders to tie crop bundles. Sisal is grown for the fibres and the fibres are in the fleshy leaves. The sisal leaves are about 1 m long with sharp pine at the end of each leaf. There are about 1,100 white creamy fibres. The sisal plant produces 2-3 leaves per month or 200 to 300 leaves during life period of 7-10 years. The leaves are removed from sisal plant at regular interval to achieve high output and increase life of plant. The most common method of extracting fibre from leaves is by beating the leaf with wooden mallet and fleshy particles are scraped with a knife on the edge of a wooden block.

Raspador: The machines are available for automatic decortications of leaves. This is called raspador or automatic decorticator. The raspador is a wheel 1.0 m in diameter and 30 cm wide on the rim on which steel bars and knifes are fastened. The wheel is rotated at speed of 500 rpm. The bottom of wheel is about 5 mm above the base plate. The operator feeds the leaf and holds on to it as it enters, due to the rotation of the drum of the machine. The fleshy parts of the leaf come out from the side of machine. After the leaf is halfway into the machine, the operator removes it, grasps the exposed fibres and decorticates the other half. About 400 leaves can be decorticated per hour. The work is tiring and requires full attention.

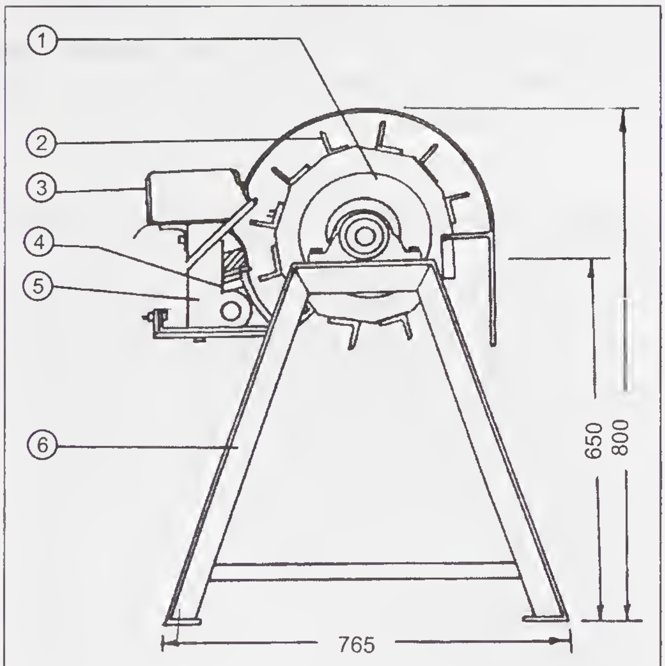

Fig. 11.14. Ramie and Sisal decorticator developed at JARI, India. 1, Drum; 2, Blade; 3, Feeding chute; 4, Counter blade; 5, Blade adjuster; and 6, Stand.

JARI decorticator: JARI Barrackpore reported machine (Fig.11.14) for decortications of Ramie and Sisal plants. It is a simple machine consists of a rotating drum with blades mounted on its surface and is provided with a counter blade on a stand. For extraction of fibre one end of the stem to be decorticated is fed into the gap between the rotating blades of the drum and the counter blade while holding the other end. The hard core and other tissues are beaten and loosened in the forward movement of leaf and the operator eliminates the same from the fibres while pulling the stem out. Then the second half of the leaf is fed and the process is repeated to complete the fibre extraction process. Two to four stem or leaves are fed at a time. In ramie the extracted fibre is chemically treated to produce finished fibre whereas in sisal the extracted fibre is only washed in fresh water and dried in the Sun.

The machine is operated by 3 hp electric motor and a worker can operate it. The output of machine is one tonne of green leaves/h. Automatic decorticator consists of essentially a drum with knives fastened on the periphery. The leaves enter the drum parallel to the axis of drum i.e. in an axial flow manner. The flesh is removed as it passes between the drum and a concave. The leaves are carried into the throat of the decorticator by means of a conveyor. The unit can process 25,000 leaves/h weighing about 10-15 tonnes of material.

During the decortications process the fibres are washed with water. The fibre is then dried combed and baled for market. Tamil Nadu Agricultural University, Coimbatore reported the development of fibre extractor

(Fig.11.15) for the crops such as jute, sun hemp and rozella (Mesta). It consists of a feed tray, set of rollers for crimping action on the stems and a beater drum. It is powered by 2 hp motor and therefore its capacity is 10 kg of fibres/h. The stems of fibrous material are fed into the tray where the rollers remove the skin from the woody portion; the material is then guided to the beater section where the skin from the fibres is separated. The wet extracted fibres then retted for 6 to 8 days in water for getting the clean fibre. The fibre is washed and dried in the sun.

Arecanut

Central Plantation Crop Research Institute, Kasorgod, Kerela is engaged in the development of technology for production and processing of plantation crops. These include coconut, arecanut, cocoa, oil palm, tea, coffee, rubber, etc. These crops cover an area of 4 million hectares. But the values of products produced give an annual income of more than ₹ 298.5 billions to the farmers. The institute has reported development of arecanut dehusker (Fig.11.16) of manual and

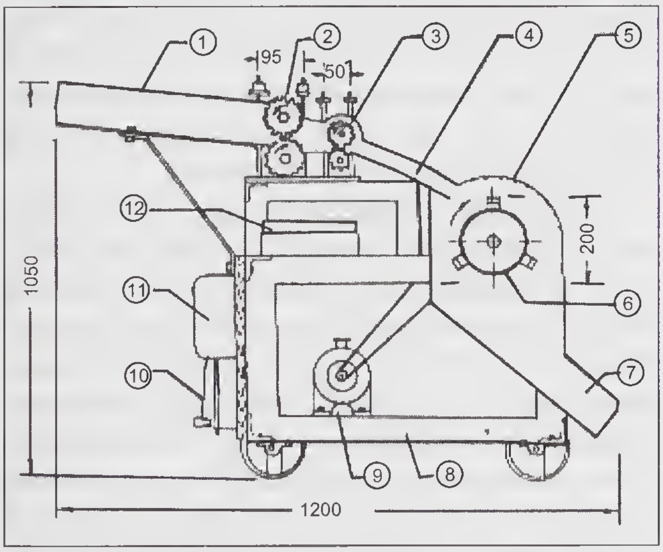

Fig. 11.15. TNAU fibre extractor. 1, Feed tray; 2, Primary feed roller; 3, Secondary roller; 4, Guide chamber; 6, Beater; 7, Fibre outlet; 8, Frame; 9, Motor; 10, Switch; 11, Starter; and 12, Plant juice collector.

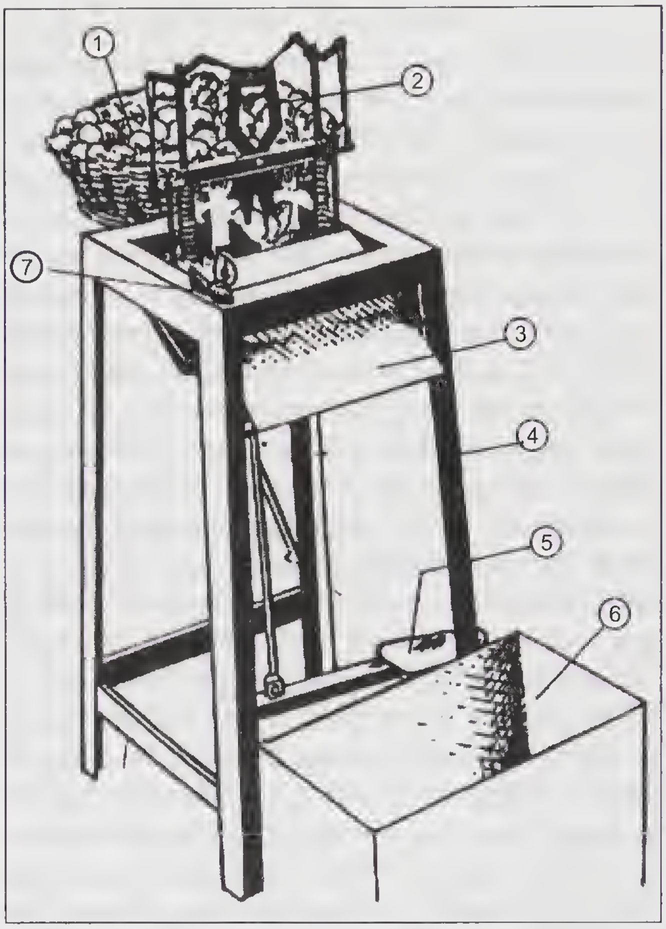

Fig. 11.16. CPCRI arecanut dehusker. 1, Raw arecanut; 2, Blades; 3, Discharge chute; 4, Frame; 5, Pedal lever; 6, Collection tray; and 7, Dehusked areca nut.

power type for dehusking the tender ripened arecanuts. The manual unit consists of a pedal operated scissor type blades. The arecanut is placed below the knife assembly, which upon pressing the pedal pierces the nut, and splits it into halves. The husk is then removed with hand. It is a safe machine for operation, as it involves no risk to the fingers of the operator. The output of machine is 50-60 kg/day. Arecanut is widely used in south and south-east Asia and Pacific region as masticator and is used as medicine, in religious and social functions. The arecanuts are harvested by skilled climbers who covers about 50-60 palms trees in a day. The harvested nuts are preserved to keep the moist chewing feel. This is done by steeping ripe arecanuts in water. Thus the inner nut is well preserved and can be stored

up to 10-12 months by blanching followed by steeping the arecanuts with potassium metabisulphate. The arecanuts are marketed as whole nuts after the process of dehusking.

Arecanut dehusker: The device comprises of a scissor mechanism, frame platform and pedal operated mechanism. The scissors are made from steel and hardened and are mounted on the frame with a guide and compression spring. The frame and platform are made of structural steel components. Two guide rods are provided with bushes and scissor mechanism with the linkage is fixed with the guide rods. The compression spring brings back the scissor blade to normal position after each operation. A bowl shaped cup with slots is fixed on the platform to position the nuts. When the pedal is pressed the lever operated blade cut the husk around the nut and as it is spring loaded it comes back to the original position. The husk which is split with the nut is taken out and removed by hand thereby separating the nut from the husk. A worker can dehusk 60 kg of ripe and dried nuts. The unit is handy for small farmers as it helps in getting full arecanuts without any damage or scratch. The farmers do the dehusking when the market price is high for the nuts. Therefore the dehusking is done mostly the storage of 6-8 months. A power operated unit has also been developed. It consists of a feed hopper, shelling drum, concave and a blower mounted on the frame. The shelling drum is mounted with hard rubber pads of rectangular shape and is fixed rigidly. The clearance is adjustable according to the size of nuts. Therefore grading of nuts is done before dehusking to reduce breakage. Concave grate sizes vary from 10×18 mm to 25 × 25mm depending upon the nut size. The power unit has capacity of 100 kg/h. Dehusking efficiency of 90% and damage of 5% was reported. However the damage is not considered as loss in quality of dehusking as all nuts are consumed in broken and sliced form. Presently the demand for Arecanuts is growing in India and the present price of nuts has touched ₹ 200/kg. Hence mechanization of processing of nuts to get best quality nuts would be desirable at farmers' level.

Manila hemp

Abaca (*Musa textiles*) is a member of banana family and provides fibre that is called Manila hemp. The name Manila in Philippines is the port from where it was first exported. Abaca is the tropical plant, which is grown in hot and humid climate with high rainfall through out the year and on a well-drained soil. Abaca fibres are light buff and lustrous in colour. It is the strongest natural fibre. It has the strength, elasticity and the resistance to salt water. Hence it is used for making twines, ropes and cloth. Ropes on ships and marines used are mostly Manila hemp ropes.

Abaca stalks are harvested at the end of 4 years of age. The plant can live as long as 25 years. New plantings are made after 10 years of harvest. The maximum of production falls off after 8 years. Abaca is harvested when the blossoms appear on the flower stalk. The stems are cut when they are 2.5 m long and sheaths are stripped off. Each pseudo stem has an outside layer which contain the commercial fibre, the middle layer with few weak fibres and inner layer with no fibres. By inserting the machete between outer and middle layer, ribbon of 6-7 cm wide are stripped off for processing. Inner pith is discarded.

Manual processing consists of pulling the ribbons called tuxies between the knife-edge of machete and a hard wooden block. A smooth knife-edge is used to produce the fine fibres, while serrated blade is used to produce coarse fibre. A blade with large serrations requires fewer efforts, wastes less material. The fine serrated blade requires more work and leaves more waste. An output of 10 kg of well-cleaned un-dried fibre per day per person is considered as good output. The fibres are hung on lines and sun dried after the stripping operation.

A power operated spindle rotating at 600

rpm can be used to pull the tuxies between the knife and the wooden block. The spindle is cantilevered truncated cone about 15 cm diameter on one end and 10 cm diameter at the other end. The length of spindle is 30 cm. It is made of soft wood as it provides sufficient friction for the tuxy.

The operator steps on the spring loaded lever to open the space between the knife and the bottom plate and insert about half the length of tuxy under the knife. Removing the foot from lever allows the tuxy to be caught between knife and the block; he then wraps the remaining end of tuxy around the spindle as the sailor would wrap a line around the capstan. The operator then pulls on the tuxy to create friction on the spindle, which pulls the tuxy between the knife and the block. Since the spindle is conical, the tuxy is easily released by moving it axially towards the small end. The operator then flips the tuxy end over end and repeats the operation until the flesh is removed from the fibres.

A power-operated decorticator is also used to produce the abaca fibres. It is similar to the one used for producing sisal. When the decorticator is used the outer sheath is not separated but the entire pseudostem is put through the decorticator. Thus first putting them through crushing rollers flattens the stems. Water is used in good amount for cleaning the fibres and washing away the extraneous material. A decorticator can produce fibre at the rate of 0.5 tonne/h.

It is noted the fibres in different crops are located differently. In cotton the fibres are attached to seed, in jute, sun hemp, flax etc they are between the outer epidermis and the core. The fibres in case of coconuts are in the outer covering of nuts and are tightly held. In other crops fibres are in the part of thick leaves. In all case mechanical means are used to extract the fibres. In many cases retting process is performed. Nowadays even the chemical retting is also being practiced. Even though retting process done in field produces good quality fibres, it is to be carried out in stagnant water which sometimes leads to skin diseases to the worker. In some cases to improve quality of fibres fungus cultures are used and retting is done in tanks made of cement or metal with clean water. However manual and mechanical means are becoming popular among the farmers to finally get the fibres of desired quality for supply in the market.

❑

12 Design Principles for Threshing Units

Feeding chute or feed inlet tray	166
Design of threshing cylinder	170
Details of threshing drum of spike tooth type	186
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High capacity threshing units (1.0 tonne/h)	189
Ultra high capacity threshing units (feed rates up to 7.0kg/s)	189

The various designs of threshers developed and used by farmers have indicated that they would like to have, a low cost, high capacity, durable machine. Further such a machine should be able to handle different crops and provide grain and straw in the desirable form suitable for market and/or storage on the farm. From technical point of view the thresher to be designed for the farmers should meet the following technical specifications, such as high threshing efficiency, minimum of grain damage and losses and full recovery of plant material to be used as animal feed or for other uses at the lowest cost of operation.

In general thresher should have threshing efficiency of 98-99%, cleaning efficiency of not less than 97% and grain damage not more than 2% which may be as cracked or visibly damaged grain and total losses (visible and invisible) within 1-2%. This level of performance of the thresher is expected for the crop under normal conditions and recommended settings of the machine. The grain output of thresher should be at least two to three times the output achieved by traditional methods of threshing employing human labour. Economic viability of the machine is extremely important factor which cannot be ignored.

The machine should be priced low so that farmers can afford and find economical to use it. It should be operated by an electric motor, as it is comparatively inexpensive source of power on the farms. The best guide for this type of machine is the one for which the cost of threshing operation should be within 5 to 6% of the value of crop threshed in most of the cereals. The cost of threshing operation depends upon the value of crop, the wages of labour and cost of thresher. The traditional methods of threshing crops manually, in many Asian countries have continued because of many reasons. The most important one being the low wages rates of the farm workers, low market value of grain and need for the bruised or tenderized straw (*bhusa*) to be used as animal feed. Fig. 12.1 shows the transportation of *bhusa* by tractor trolley.

Fig. 12.1. Transport of bruised wheat straw (*bhusa*) by means of tractor trolley.

The straw in the developed world is considered as a product of little value but it is of utmost economic importance to the Asian and African farmers. The economic value of straw has been equated to about 40% of grain value in India. Hence it cannot be neglected by the farmers. The advantage in traditional system is the ease with which workers carry out the job without training or skill development. In case of thresher the machine is to be looked after by skilled or trained worker. One has to depend on the source of power/energy for operation during threshing season. The spread of mechanization is slow in many parts in rural areas because of slow pace of development of infrastructure such as rural road, rural electrification, etc. in most of the Asian, African, Latin American countries. However in 21st century, things have shown improving trends leading to farm mechanization because of wage rise of farm labour.

The cost of machine depends upon the value of raw materials, the manufacturing techniques used to produce, the labour cost of its production and the taxes. Thus lightweight machines are suggested to reduce cost of production and transportation charges, etc. Thus the designer considers the number of alternative steps to develop the most economical design to meet the needs of local farmers. The various types of threshers developed and used by farmers are presented in Table 12.1.

It is not easy to optimize one design to meet the requirements of all crops. Therefore design of few threshers must be considered to suit the crops raised by the farmers in the region or a country. A thresher consists of the feeding tray, threshing unit, the separation and cleaning units. In most of the low cost units, the straw walker type separation is eliminated. The straw is considered as a valuable component of the crop. Therefore, all of it is to be recovered in the form as desired by the farmers.

The threshing units used are mostly two types, namely the spike tooth cylinder or beater drum type provided with wire mesh type or rod type grate or concave. The axial flow thresher concept is used when the condition of straw is at high moisture level as in case of rice crop. The radial flow is used when straw

Table 12.1. Thresher types and their suitability for crops reported for Indian conditions.

Type of Thresher	Suitability for crop	Quality of straw	Power requirement (kW/tonne of crop)
Hammer Mill radial flow	Wheat	Very fine *bhusa*	12-15
Syndicator (Chaff cutter)	Wheat	Fine bruised straw (*bhusa*)	6-8
Spike tooth	Multicrop	Fine bruised straw	6-9
Axial flow	Paddy	Very long	3-4
Rasp bar cross flow	Multicrop	Long	5-6
Wire-loop stripping type	Paddy	Full length	5-6
Multicrop or combination of axial and radial flow type	Most of the crops	Bruised or long as required	5-6

is required in bruised form, and the crop is dry, which is mostly practiced in wheat crop. The bruised wheat straw *'bhusa'* produced by the wheat thresher is directly used as animal feed. In case the wheat straw is not bruised, the awns of wheat ears and long length of straw with nodes would be produced during threshing. This type of straw *'bhusa'* produced is not palatable to animals. When the straw is required in full form the ear head threshing is recommended as in rice and pigeon pea. Even in rice crop the quality of straw depends upon variety raised by the farmer. In case farmer likes to use straw for thatching the hut, he would prefer it in undamaged conditions.

The cleaning of grain involves pneumatic and mechanical methods of cleaning. Aspiratory blower is used to suck out most of the non-grain mass from the grain. In hold on method, the cleaning is done due to winnowing action of the blower otherwise the advantage of natural wind has to be taken for cleaning. The energy requirements of different threshing methods are to be considered as the available range of power units is small in most of the places; hence designers should pay greater attention to available power units in the regions (Table 12.2).

The other two factors, which are considered essential are (i) safety of the worker and (ii) minimum exposure to noise and dust encountered. The safety provisions made on machines is highly desirable. The prevention of accident is important as continuous operation of machine during threshing season puts pressure on the operators leading to fatigue. The dust and noise are other factors, which often are not given proper attention of designers. The noise levels and dust quantities are high for the workers operating the thresher especially in dry season. In most of Asian countries land holdings being small, but the thresher will be economical only when it is used for 250-300 hours of operation per year. As most of the farmers use the machine for less than the figure quoted, it is because of this reason that the custom hiring of threshers has become a very successful practice on India farms.

The major parts of thresher are (i) feeding chute, (ii) threshing unit, (iii) straw or non-grain material conveying unit, and (iv) the cleaning shoe. All these units are mounted on a frame. A prime mower with suitable drive transmits powers to the machine and the unit is fitted with wheels for its mobility on the threshing floor or farmstead.

Feeding chute or feed inlet tray

The threshers are provided with a crop feeding tray or trough or chute to feed the crop to the threshing drum in manually feeding machine. In small size threshers the manual feeding devices are provided to reduce the overall cost of the machine. However, this would limit the output capacity of the machine. The manual feeding machine would have limitation on its output capacity,

Table 12.2. Energy requirements for different threshing methods

Crops	Energy required For threshing One tonne of crop in kWh,			KWh per tonne of grain
	Manual beating	Bullock trampling	Tractor treading	Power thresher
Wheat	7.45	47.20	38.80	19.75
Sorghum ears	10.65	13.70	-	6.55
Pearl millet	10.65	13.70	-	7.90
Maize cobs	4.10	Not practiced	-	3.95
Gram	-	20.65	26.30	15.80

Source: Majumdar (2003).

which is within 250-300 kg/h. This is because of capacity of workers to bring the crop to machine and feed it uniformly for threshing and the amount of grain in the mass of crop. In some designs the height of feed inlet is at high level and therefore the operator is made to stand on a platform and other workers are engaged to move the bundles of crop for the threshing. The percentage of grain in the plant material varies from variety to variety and for the same crop depending upon the crop production parameters.

Table 12.3 gives the average % of grain at 8-10% moisture in different crops.

Table 12.3. Average percentage of grain reported at 8 to 10% moisture in different crops

Crop	Grain, %
Paddy	38-40
Wheat	40-46
Maize cobs	80-85
Gram	45-50
Pigeon Pea	26-29
Soybean	35-38
Sunflower heads	38-41
Mustard	26

The feeding tray of a thresher is made wide to hold the crop and feed evenly into the machine. The feeding chutes on threshers are also made folding type for ease in storage and transport. For the chaff cutter type wheat thresher, the feeding chute was fitted with feeding rollers and the rollers are powered with gear drive. Many times the hopper is not properly protected with sheet cover. Therefore it was reported that because of lack of safety features, large number of accidents were occurring on the farms whereby the farmers/ operators lost their limbs during the threshing seasons mostly in the northern wheat growing states of India. The accidents in threshing season became so large that the Indian Parliament had to pass an act for the safety of workers in 1980. It was made compulsory to provide safe feeding chute on the wheat threshers and also provide insurance coverage to farm workers in case of wheat crop threshing.

Safe feeding chute: The major criteria for safe feeding chute was to keep its length long enough so that the fingers or hand should not touch the feeding rollers or beaters of the threshing drum during operation. Further to avoid accidents in case the farmer intends to feed the crop from the top or side of feeding chute, the top portion of the chute be covered so that the fingers should not touch any of the moving parts when the arm of the operator is bent at the elbow. The base of chute and top were given slope and tapered so that crop can be fed easily in the machine or threshing cylinder. Thus dimensions of feeding chute were standardized and are given in the Table 12.4 and the shape is shown in Fig. 12.2.

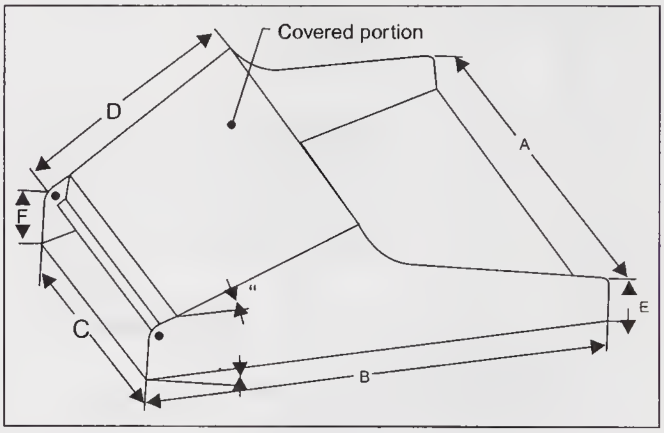


Fig. 12.2. An improved feeding chute (Manual feeding of crop bunches).

The dimensions B, D shall be 900 mm (minimum), 450 mm (minimum). The value of angles shall be 10 to 15 degrees for hammer mill and drummy type and 0-5 degrees for chaff cutter type and –10 to +15 degrees for spike tooth type machines.

Feeding hopper for bulk feeding of crop (Fig. 12.3): In threshers of high capacity the hoppers of throw in type are provided where the crop is thrown inside the hopper. This hopper is fitted with a shaft mounted with star wheels to feed crop evenly into the threshing drum. These are provided on thresher of 7.5

Table 12.4. Recommended dimensions of feeding chute used on hammer mill, chaff cutter and spike tooth type threshers in India

Size of prime mover kW (hp)	A, in mm	B, in mm	E, in mm	F, in mm
For hammer mill drummy and chaff cutter type threshers				
3.7 (5)	500	350	50	125
5.5 (7.5)	550	400	60	175
7.5 (10)	600	450	60	190
11 (15 and above)	650	500	60	200
For spike tooth type threshers				
3.7 (5)	440	350	60	190
5.5 (7.5)	480	400	60	190
7.5 (10)	540	480	60	190
11 (15 and above)	590	530	60	210

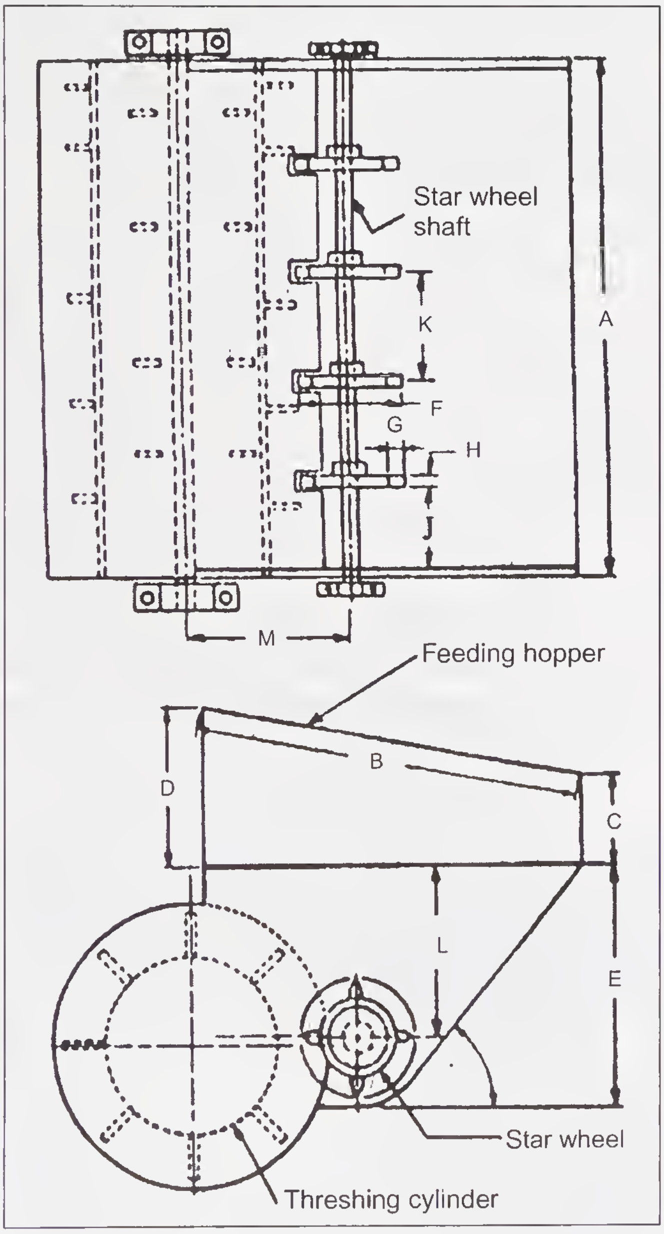


Fig. 12.3. Feeding hopper for bulk feeding of crop in bunches.

kW and higher power rating. The details of the hopper are shown in Fig.12.3 and dimensions are given in Table 12.5.

Chute for syndicator type thresher: The Fig. 12.4 indicates the details of safe feeding chute used on syndicator type thresher. The chaff cutter type-feeding device installed on the thresher had insufficient sheet metal protection from the feeding rollers as the operators had tendency to push the material manually to get maximum output from the machine. Thus they exposed themselves to the accidents whereby they lose their fingers, hand or even the arm due to carelessness during operation. Thus the feeding chute provided on

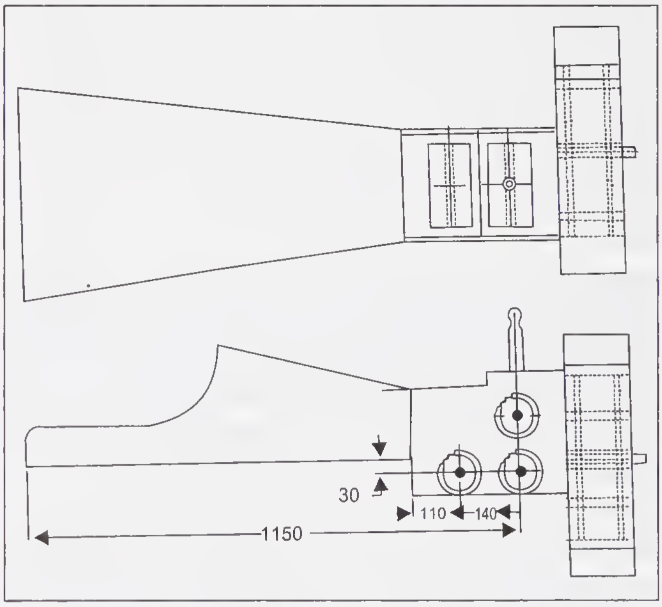


Fig 12.4. Safe feeding chute used on syndicator type thresher (chaff cutter type feeding device).

Table 12.5 Recommended dimensions of hopper and star wheel for bulk feeding of crop in threshers

Size of prime mover, kW	B min, mm	C min, mm	D min, mm	E min, mm	F min, mm	G min, mm	H min, mm	α +_ 5, degrees
7.5	900	180	340	475	280	45	20	50
11	900	200	370	500	280	45	20	50
15	925	220	400	535	280	45	20	50
18.7 and above	950	240	430	565	280	45	20	50

(*Source:* IS 9129: 1979)

thresher was to be covered properly so that the hand of operator should be away from feed rollers. In latest design the drive is provided with a lever so that as hands is close to rollers it can push lever to reverse the motion of feed rollers.

Feeding tray: For the threshers with rasp bar threshing drum or spike tooth thresher a simple feeding trough or tray is provided. The feed inlet plate should be tangential to the rotation of threshing drum and it would have tendency to pull in the crop. For threshers where crops like maize and sunflowers are to be threshed they need hoppers that are supposed to hold the cobs or flower heads. Therefore to prevent back flow of grain the hopper is raised upward and cobs are fed as in over-shot type threshing drum-concave arrangement.

The feeding tray/trough on paddy thresher developed at IRRI; Philippines is shown in Fig. 12.5. The feeding trays are made from mild steel sheet of 1.0 mm thickness and are reinforced by mild steel angle or flats at the appropriate places. The design of feeding tray should take into account the comfort of operator in feeding the crop as well as it should protect him from accidents.

Hopper for maize cobs: It is a hopper of overfed type where cobs are fed into bulk. The shelling cylinder moves the cobs axially along the length of cylinder and shells the grain from the cobs. As the maize shelling is comparatively easy therefore the cobs are to be fed into the hopper in bulk. As soon as the material moves inside the cylinder, more cobs

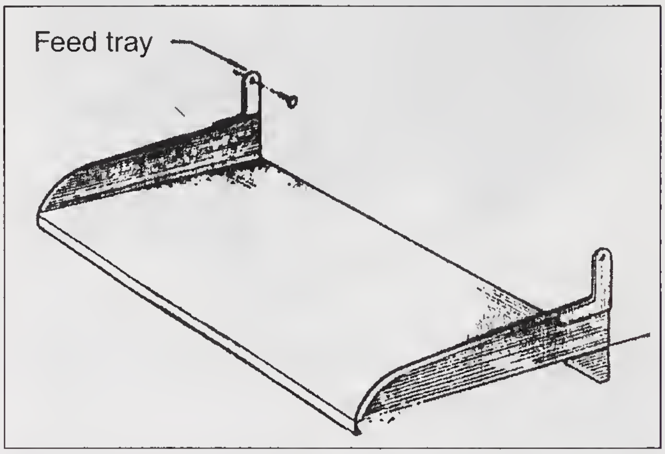


Fig. 12.5. Feeding tray used on IRRI designed rice thresher (wide tray for stacking crop).

are fed into the machine. The hopper is shown in Fig.12.6.

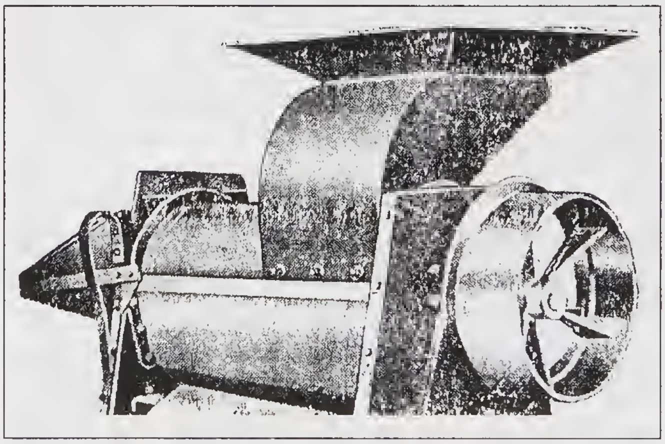


Fig. 12.6. Feeding hopper used on sheller for maize and sunflower heads.

Hopper for feeding crop in bunches (Fig. 12.7): Hopper is always at a height, therefore, the worker has to stand on the platform and thus requires one more helper to assist

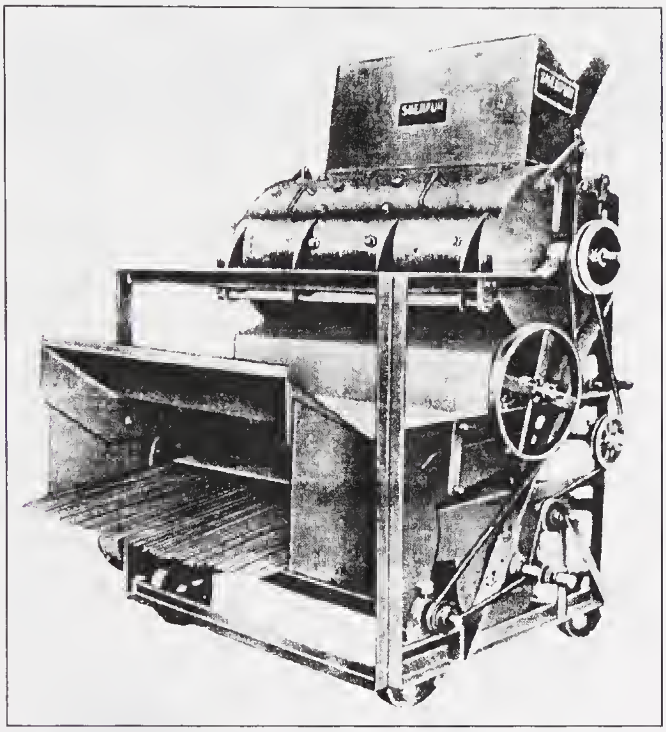


Fig. 12.7. Hopper for feeding groundnut crop in bunches in the thresher.

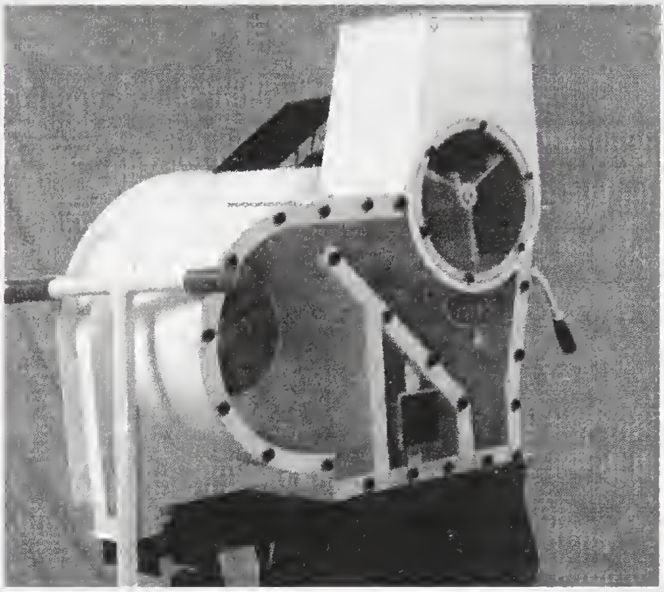


Fig. 12.8. Feeding hopper for single ear thresher for feeding ear heads only.

him to lift crop from ground level and feed in the thresher without making extra effort. Normally, it is noted that height of feeding hopper on threshers is at high level for the workers. Most often the workers use the platform to stand and feed the crop. The feeding hoppers used on groundnut thresher are mostly at sufficient height from ground level so that the flow of material is smooth due to force of gravity.

Feeding hopper on single ear thresher: The feeding hoppers used on single ear threshers are shown in Fig. 12.8. The feed hopper in single ear thresher has a flap provided to hold the plant within hand and insert only the ear heads to be threshed. Thus only plant ears are pulled in and hand is safe as the width of opening at feed inlet is less than the size of fist of worker. Thus depending upon the thresher to be designed the size and shape of thresher be selected.

Design of threshing cylinder

The design of threshing mechanism cannot be taken up on theoretical considerations because there is lack of knowledge of absolute values of kinetic and dynamic quantities which have the interaction with crop components namely grain, ears, husk, and straw. It is not easy to estimate the real values of the above factions under threshing process. The threshing studies are mostly limited to study the behaviour of crop during threshing and these are directed to study the forces, energy and speed necessary to remove the grains from the ears, passage of grain through the concave and the breaking or damage of the grains and braking of the straw.

The other studies are conducted to establish a link between the efficiency of threshing with machine design features and crop characteristics. Hence, the design of threshing cylinder or concave was based upon the field experience of working with machines for many years and these are taken advantage of in the development of the new machines or improve the existing ones.

For the design of thresher, the selection of rasp bar and spike tooth type threshing cylinder would be the most appropriate choice as they can handle most of the crops. Since the size of farms in most of the developing

countries are small and about 60-70% of land holdings are in the power range of 2–5 hectares size, it is unlikely the power availability on hectare basis would increase drastically. Thus need for thresher for the small farms would be in the range of 3-5 hp size. The large farm holding units mostly own and use tractors and they would need bigger size machines of 1-2 tonne/h capacity but the number of such units would not be very large. Table 12.6 gives the size of land holding and the size of thresher and source of power required.

Table 12.6. Recommended thresher size based on land holding capacity of Indian farmers

Average land holding, ha	Thresher size, kW	Power source required, kW
10	3.7	3.7 (electric motor); 5.5 hp engine
20	7.5	7.5 electric motor or 15 hp engine
30	11.2	15-22.5 tractor
40	15.0	22.5-25 tractor

The economic analysis carried out at IRRI, Philippines for a simple low cost portable thresher (costing approximately. US$500) indicated a break-even point of 36 tonnes / year of crop threshing by the machine at the price level of 1985. The same was determined in India as the cost of 5 hp threshers in the price range of ₹ 6,000-8,000 to be viable for Indian conditions during the same period.

Gupta *et al.* (1986) developed the mathematical model for selecting wheat threshing system for farms in North India. They considered the crop area, power source used, fixed and operating costs, total cost of threshing of grain, custom work, system hours and system cost and least cost threshing system. They reported the analysis for different types of threshers used for threshing wheat for the farms up to 20 ha area (Fig. 12.9). It was seen that a thresher of 200 kg/h was able to meet the requirements of farmers' sowing area up to 8-10 ha. The least cost of threshing for

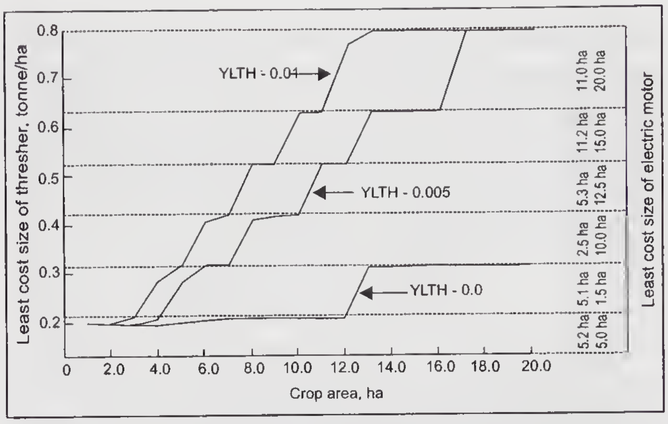


Fig. 12.9. Least cost of threshing with beater type thresher for farms up to 20 ha growing wheat crop (*Source:* Gupta *et al.* 1986).

the spike tooth thresher of 3.75kW unit was reported in the range of ₹ 55-62/- ($ 1.1) per tonne of grain, for the 5-6 ha farms.

In most of wheat thresher used in developing countries, the manual feeding of crop is the trend and, therefore, the availability of labour to operate the machine is an important factor. For the machines of 200 kg/h grain output one would require minimum work force of 3 workers.

Needless to report that even to have a power supply of 3.75 kW at small farm levels in rice regions of India is still a distant dream and even if it is available, the farmers would not be able to pay the cost of electric power because of their low paying capacity. This is the main reason that even in twenty first century the farmers' would like to have rice thresher powered by single-phase ½ hp size motor and grain cleaner of same size in the states of Bengal, Bihar, Orissa and North East Hill States (rice growing regions) to take care of their threshing needs. However, the rich and wealthier categories of farmers of rice growing farmers of Northern India, have accepted the rice wheat threshers. The custom hiring of large capacity thresher is also very much in practice.

Design of cylinder: The design of cylinder involves the determination of diameter of cylinder, length of cylinder, the arrangement of spikes, the size of spikes, the number of rows

of spikes etc. The other most important factor is the power input to the cylinder to overcome the threshing resistance of the crop feeding during operation. According to Goryachkin the relation gives the power required for threshing cylinder as follows:

$$75\ N = m \times V^2 / (1-f) \qquad (12.1)^*$$

Where,

N, engine rated power; m, mass flow rate of crop in kg per second; V, peripheral velocity of the cylinder set for threshing; and f, coefficient of resistance of material rubbing in the working slit of drum and concave or the concave clearance.

(*List of abbreviations used in equations are given on p. 191.)

The value of coefficient f depends on crop. It is in the range of 0.65-0.75 for rasp bar type cylinders for wheat and 0.7 to 0.8 for peg tooth type drum. In case the value of N, V, and f are known the value of m can be calculated from the above equation. Therefore in most of design books the information gathered on the threshing cylinder speeds for different crops along with the concave clearance for minimum of seed damage is provided for the designers. The above relation is the simple form of expression. It does not take into account the energy consumed in imparting the impact forces on the crop material and also the mass of system and its rotational energy etc.

Example: If the engine rated power is 5ps, cylinder speed is 20 m/sec, value of f = 0.7 then determine the crop mass flow rate of threshing cylinder.

$$m = 75 \times 5 \times 0.3 / 20 \times 20 = 112.5/400 = 112.5'400$$
$$= 1.125/4.0 = 0.281\ kg/sec = 1000 kg/h$$

This value is for a 1.0 m wide cylinder. The above equation is most generalized form to determine the mass flow rate for the thresher. It does not take into account the cylinder parameters, concave clearance and crop parameters.

The crop material is fed into the working gap created between the circumference of the rotating drum fitted with rasp bars and the concave surface. It is kind of sieve formed by rectangular steel bars placed at set intervals parallel to the drum axis and a series of wires, passing through the holes in the bars. Thus concave encloses a certain portion of threshing drum through a certain amount of angle known as wrap angle. The wrap angle is 120 to 160 degrees. The inlet concave clearance or gap is 10 to 20 mm and it converges gradually at the end and it is kept equal to the size of grain or a few millimeters so that the grain is separated from the ears. The motion of drum compresses the crop layer between the concave and the rotating drum surface and there the material is subjected to radial vibrations during the time required for the particular layer of crop to be sifted through the concave slit. Thus due to beating action on the layer of crop forced radial vibrations are produced and the frequency depends upon the number of strokes during the unit time for a particular layer of crop to be sifted through the working slit. The vibrations help in sifting of grain through the layer of straw mass. The effectiveness of threshing process is better when the grain is ejected out of concave grate and only a small portion is ejected out with the straw through the outlet slit of concave.

Factors affecting threshing: The effectiveness of threshing is dependent on many factors. These are described as: (i) Properties of crop material, such as crop type, variety, tearing or crushing strength of stalks, moisture content of grain, straw grain ratio and other green matter such as weeds etc in the crop; (ii) Threshing unit design features such as type of drum, operating speed, number of bars and their shape, concave length and angle of cover, concave clearances, shape and distribution of concave bars; and (iii) Operating conditions such as crop feed rate, thickness of crop layer, its density and point of contact of the crop material being fed in the threshing unit.

Thus the threshing performance is described in terms of the amount of grain threshed or separated from the ears and the grain fallen from the concave into grain pan. The rest of grain separated and unthreshed, and straw is released on the straw walkers.

In case of crop with higher moisture level the coefficient of friction of crop on crop and crop on steel bars of concave is high therefore threshing action is less effective as in dry crop. In this case, the sifting of grain through the moist crop layer is less. Thus threshing of moist crop requires more energy to separate the grain from the ears. The falling of grain layer through the concave grate is less thus the grain losses tend to increase in such conditions and feed rate is low.

Hence the threshing action on crop should not only separate the grain from the ears and the separated grain should fall through the concave, but the ideal situation would be when all the grain is separated and falls through the concave before the straw is ejected on the straw walker. The experimental studies conducted in number of countries have shown that 60 to 75% of the total grain in the crop falls through the crop and from the concave grate length. The rest of separated grain is carried along with the straw walkers where it is sifted and returned to the grain pan. This amount of grain in straw can be as much as 20 to 23%. About 1-2% of grain is lost in the straw falling from the straw walkers.

The initial approach of designers of combine harvester was to reduce the straw walker loss by increasing the length of straw walkers to help sifting of grain from the straw mass. The level of sifting at the concave is less because the time duration for the grain to sift through the straw mass is very small in cross flow type threshing units. In the initial period of mechanization as the crop yield levels were only 2.0 -2.5 tonnes per ha and machine were of small size the losses were within permissible limits. But with the introduction of high yielding varieties the amount of grain losses due to problem of sifting of grain from the straw mass was high and not acceptable to the farmers using combine harvesters. The losses reported were high especially in Canada where farmers practiced the use of combine harvesters on the windrowed crop of wheat.

Therefore the research was conducted during 1960-70 to improve the method of threshing and separation of grain from the mass of threshed material at the concave and straw walkers. The studies showed that the sifting of grain at threshing unit can be achieved up to 92-95% when the stalk length of crop is reduced to 20-25 cm and as the length increased the sifting reduced.

The sifting was also more when the drum speed was more and the crop ears were fed first into the threshing unit. These studies were conducted by Arnold at NIAE, UK. Thus studies conducted were to study the effect of cylinder diameter, concave length, drum speed and crop variables on the levels of sifting of grains at the concave.

It was reported that problem of sifting was less when the quantities of crop straw handled were less, and the crop feed rates were up to 2-2.5 kg/s. When crop yield levels increased to 6 tonnes per ha, the machine had to handle crop feed rates which were twice the previous rates. Hence, the level of grain losses from the straw walkers increased to unacceptable levels because the out put of threshing was increased by increasing the speed of threshing drum using the same combine harvester.

With increase in feed rate to the threshing unit, there occurs a higher acceleration of the grain layer in the working slit with small diameter than with a greater drum diameter and identical length of concave surface. Thus threshing and sifting can be achieved better with bigger or larger drum diameters. However, with large diameter but with same area of concave surface the sifting capacity is increased insignificantly. Thus using large size drum diameters, the grain output can be increased using concave of size where wrap

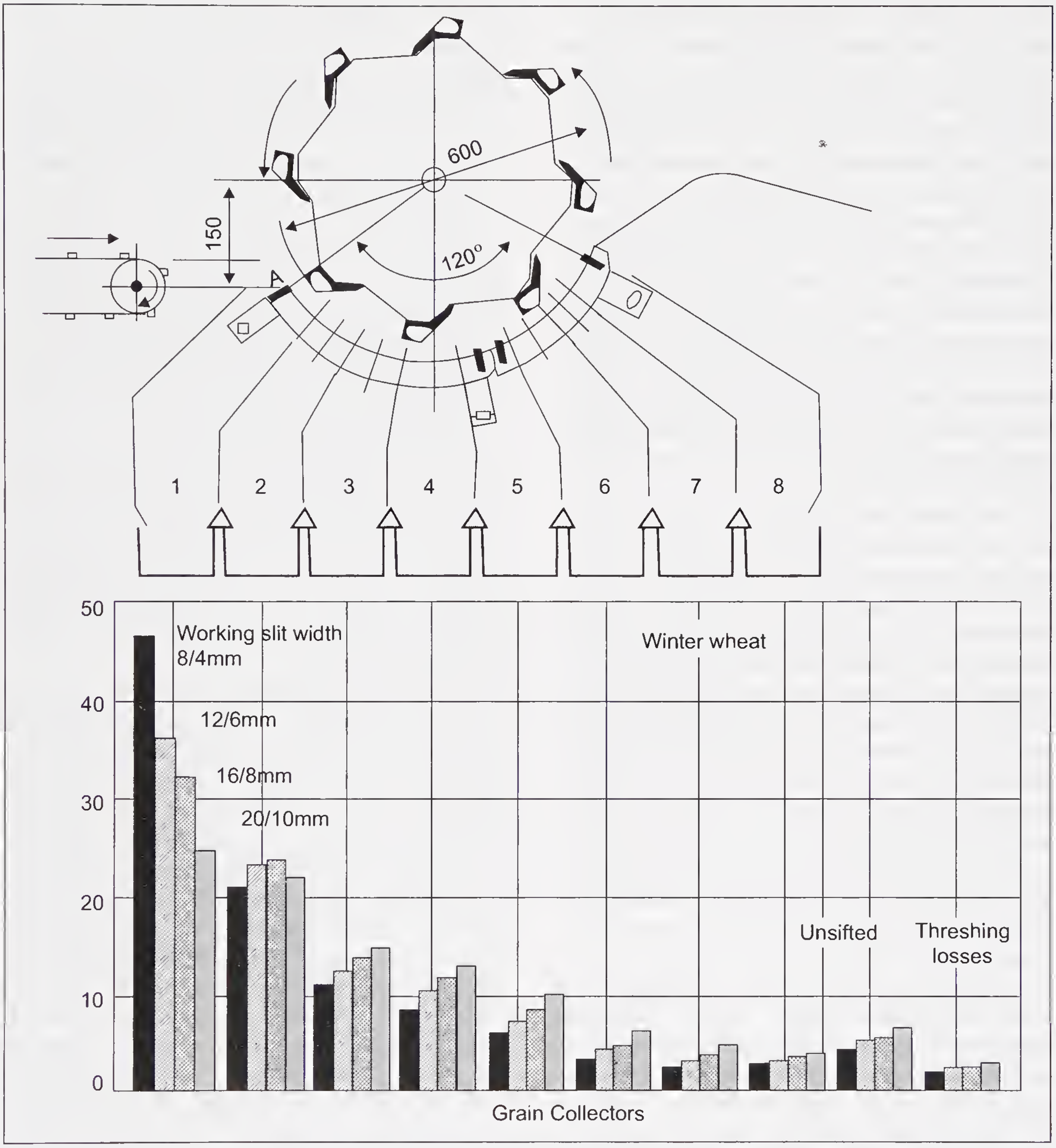


Fig. 12.10. Amount of grain sifted at the concave portion by rasp bar cylinder at different concave clearances for wheat. (*Source:* Kanafojski and Karwowski).

angle is more than 90 degrees.

It was reported that the higher length of concave, with higher revolution of drum causes increase in the number of threshing strokes on the crop resulting in better threshing action and sifting of grain, therefore reduces grain losses. It also increases the feed rate of crop. The elongation of concave length and increase in the wrap angle to increase the threshing rate of crop is rational up to certain extent only.

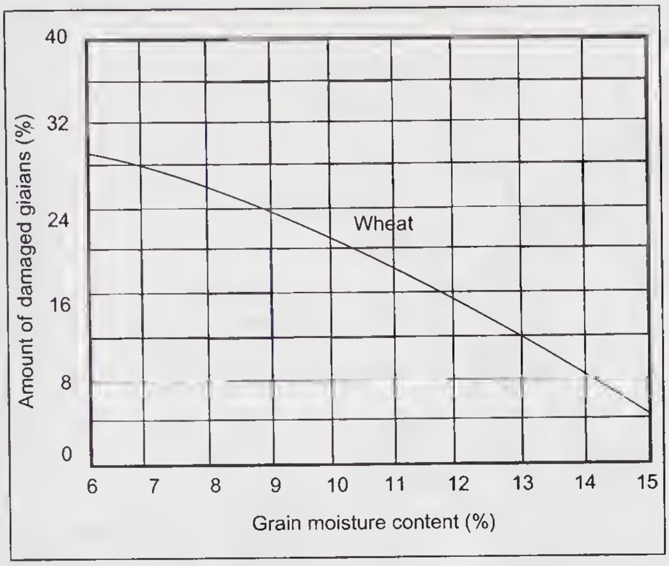


Fig. 12.11. Effect of grain moisture content on grain damage during threshing of wheat.

It is sufficient to investigate the amount of grains sifted by the individual sections on the concave from the inlet to outlet opening because it is noted that there is also greater damage of the grain at the final section of the concave. Hence, it was concluded that concave cannot be excessively lengthened. This is because of the convergence type of working slit. Thus increasing the feed rate can increase the grain damage. It means the amount of broken or damaged grains of low germinating capacity.

Hence the factors which are conducive to grain threshing do affect the grain damage. Further if the grain has low moisture content they are susceptible to grain damage during threshing (Fig.12.10, 12.11).

The sifting of grain from the threshing unit at concave and on straw walker length was determined by using the test set up as shown in Fig. 12.12 by Reed *et al.* (1974). The grain was collected at the concave and at the cylinder beater and grain and material other than grain (MOG) from straw walker which was divided at 30.45 mm interval of length. The results of studies are shown in Fig.12.13.

It would be noted that grain not separated at straw walkers increased to a high level as grain feed rate on walkers increased. It also increased as the MOG also increased. Thus it was concluded that the separation of grain should be achieved at the threshing unit.

The studies conducted in UK by Boyce *et al.* (1974) on sifting of grain for the combine

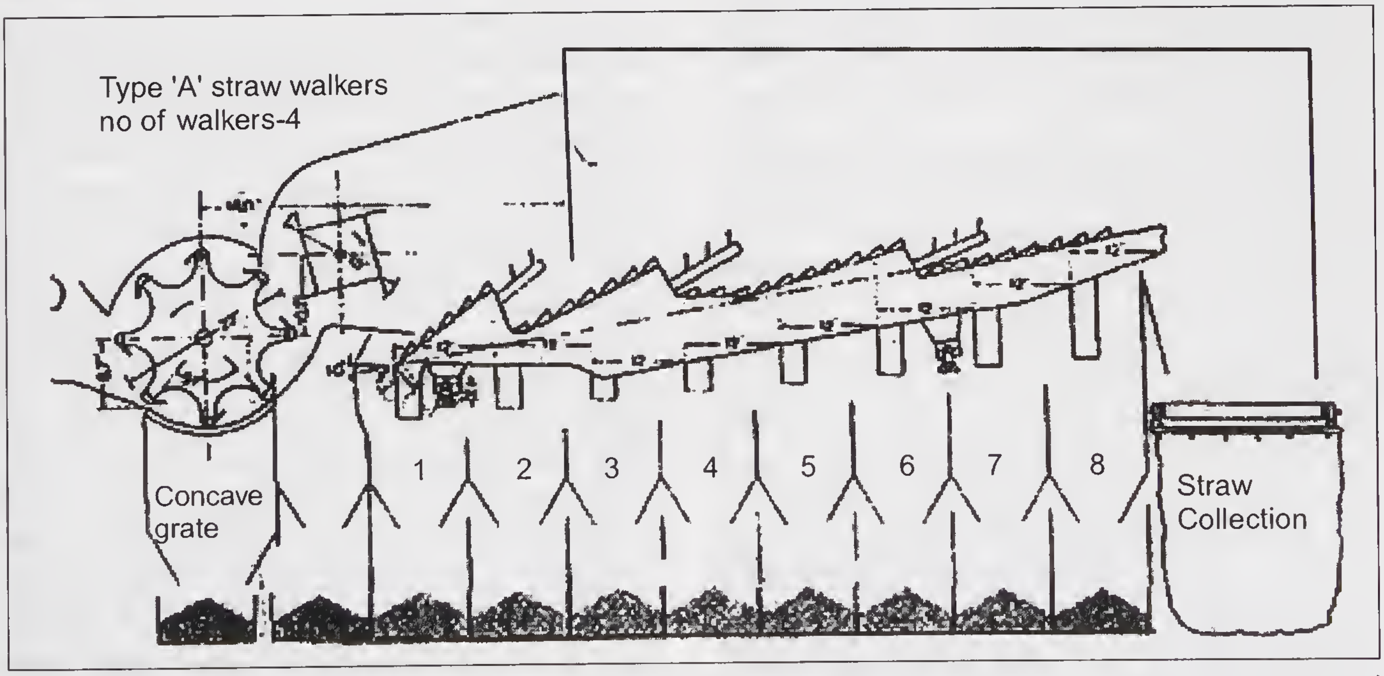


Fig. 12.12. Laboratory set up used for study of straw walker performance by collecting grain at concave and under eight locations of straw walker (*Source:* Reed *et al.* 1974).

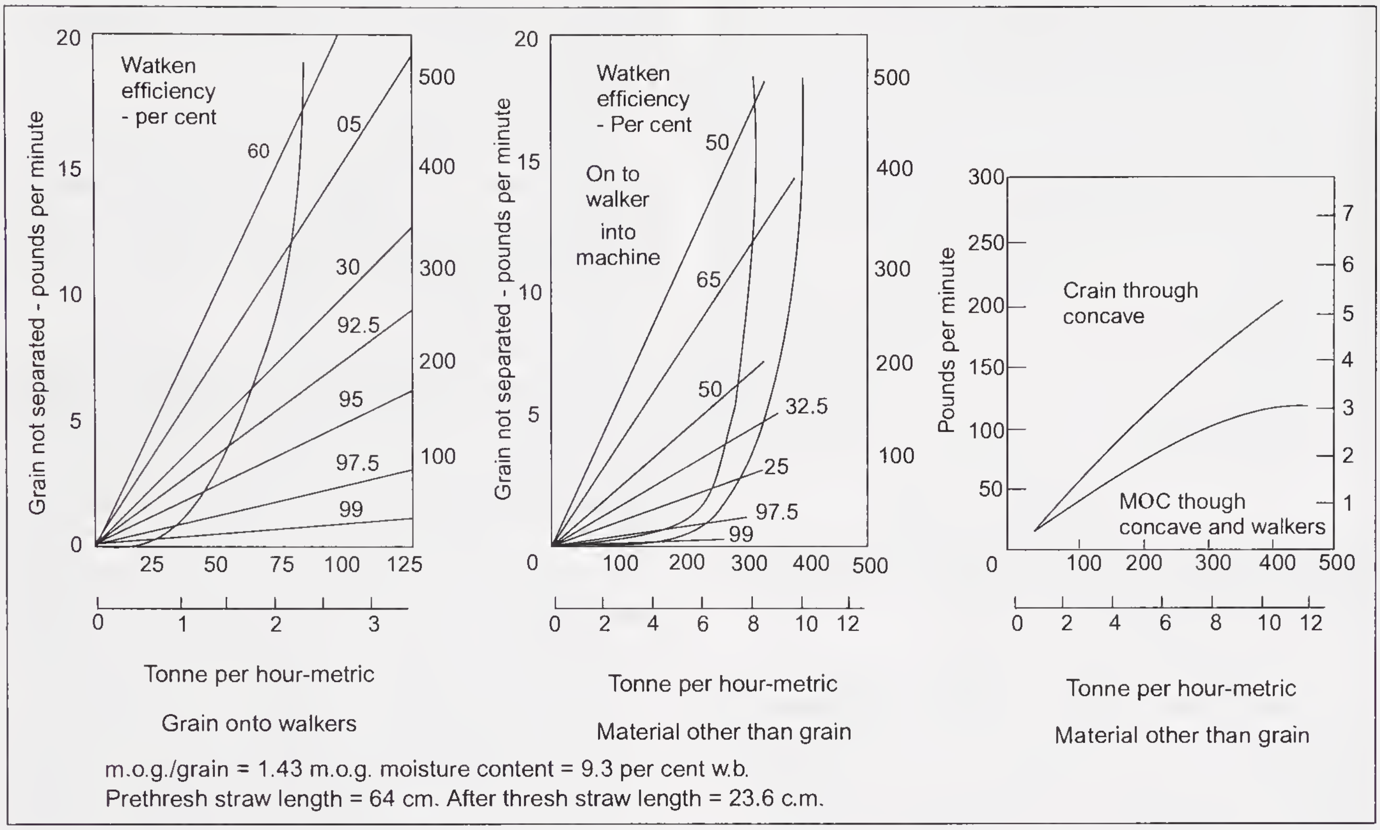


Fig. 12.13. Performance of straw walker in terms of grain separation from crop at concave and grain shifted on the straw walker (*Source:* Reed *et al.* 1974).

harvester is reproduced (Fig.12.14). Here it is noticed that sifting of grain at concave was 65%. The separation of grain on straw walker was not uniform along its length. Thus increasing the length of walkers would not give the better results.

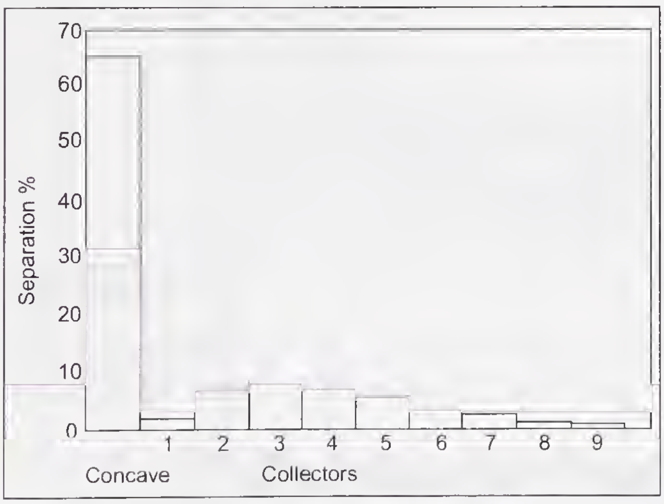


Fig. 12.14. Distribution of grain sifted from combine threshing unit and straw walker units (*Source:* Boyce, Pringle and Wills; 1974).

The Fig. 12.15 shows the effect of using the curtains at the straw walkers at the front and rear end. It was reported that the sifting of grain was more after the first curtain. The recovery of grain from rear end was less. To recover

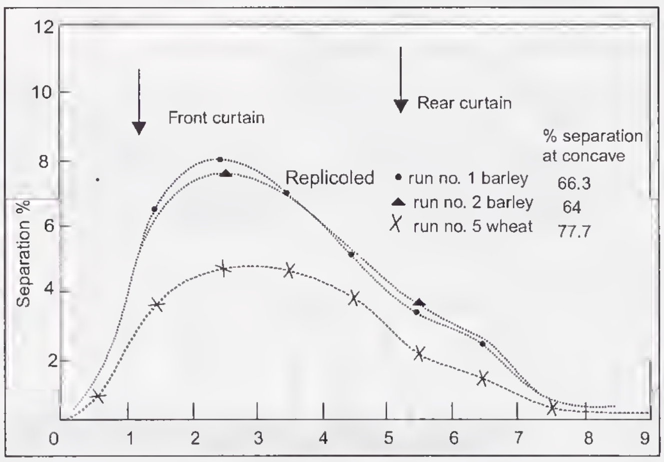


Fig. 12.15. Performance of straw walker with curtains in terms of separation of wheat and barley grains along its length (*Source:* Boyce *et al.* 1974).

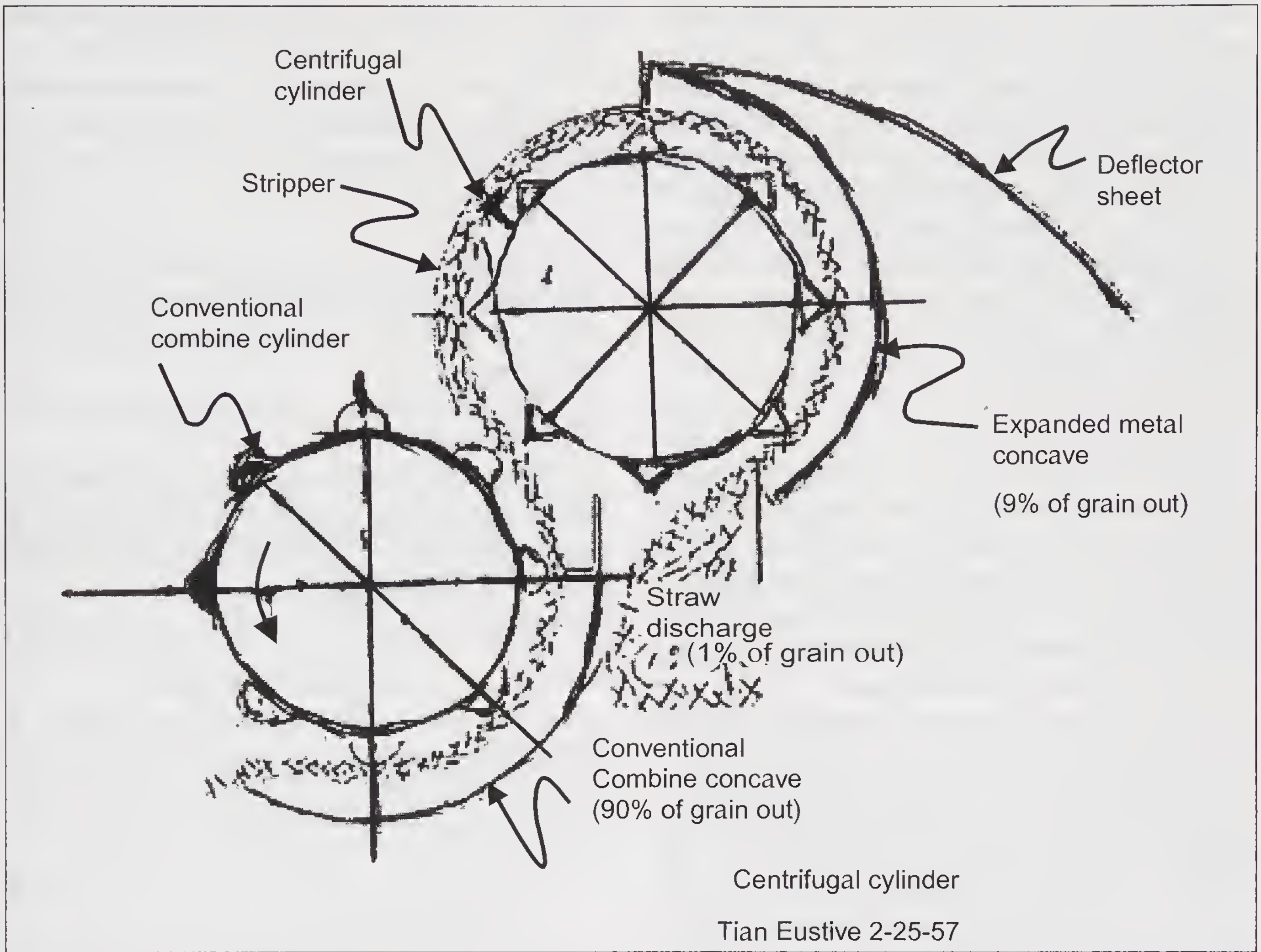


Fig. 12.16. Experimental threshing unit for the maximum recovery of grain at the concave level (*Source:* DePauw *et al.* 1977).

maximum of grain at the threshing unit, the International Harvester Company developed the extended concave using two cylinder one above the other. This arrangement helped them to recover 99% of grain. The studies conducted in various countries on threshing of crop at high feed rates, it was reported that the non sifting of grain at the straw walker was the main cause of increased losses due to formation of straw mat. It was possible to handle crop at higher feed rate in the threshing units but losses increased due to non sifting of grain at the concave and straw walker. These results are shown in Fig. 12.9 to Fig.12.15 of experiments conducted by research workers in Russia, Canada, UK and USA. Fig.12.16 shows the design of threshing drum developed at International Harvester Company USA, which was able to sift most of grain at the threshing unit by using the twin cylinders and extended concave. The recovery of 99% of grain was reported. Thus the concepts of axial flow threshing unit were developed to overcome the losses due to separation of grain from the crop at high feed rates of crops.

Length of cylinder: In cross flow threshers, the pulling capacity of threshing cylinder of large diameter is found higher than the small drum. Further the specific power requirements are less for the small diameter drum and at low peripheral speeds, while the quantity of material threshed by useful unit of power

is higher with small drum at low speed of operation. However, the small diameter drum has the tendency to get wrapped with straw if the length of straw is large i.e. above 70 cm as in wheat or rice varieties. For these reasons the cylinder drum diameters size is selected in the range of 500-600 mm. This size of drum is widely used on wheat-rice threshers. One simple equation which has been derived for the flow of material for the cross flow type cylinders is as follows:

$$m = l \times s \times \gamma \times c \qquad (12.2)$$

Where, m, feed rate, kg/sec; l, length of working slit i.e. cylinder length in m; s, width of working slit in m; γ, bulk density of material in the working slit and c, coefficient of utilization of working slit the value is (0.85-0.90). Thus knowing the values of m, s, c, γ the length of cylinder is determined.

Power requirement for threshing cylinder: The threshing action in cross flow thresher is accomplished by repeated impact and deformation of plant mass caused by the beaters (spike teeth or rasp bars) over the concave bars. The total tangential force acting on the cylinder bars consists of the impact force and the pulling force. The equations for the threshing drum operation have been described in details by Klenin *et al.* (1985). These are covered here to explain the theory for design considerations. Thus total force (P) on threshing drum during operation is given by equation:

$$P = Pi + Pt \qquad (12.3)$$

Where,
Pi, impact force, and Pt, tangential or pulling force.

The impact force is determined by considering the equation of impulse force with change in the moment of plant mass.

$$Pi \times T = \Delta m \times (U2 - U1) \qquad (12.4)$$

Where, m, feed rate in kg/sec; U1, speed of plant mass before the impact. m/sec; U2, speed of plant mass after the impact, m/sec, and m, the plant mass which receives the impact.

In practical cases U1= 3 to 5 m/sec and the value of U2 = less than the speed of beaters of the threshing cylinder.

$$\text{Let } U2 = \alpha U \qquad (12.5)$$

Where, U, velocity of beater and α, coefficient which depends on many factors but the predominant factors are moisture of straw, straw length, etc.

The value of α = 0.7 to 0.85 as reported from the tests.

The force Pt is the resistance to the shifting of the plant mass in the threshing unit, it is accompanied by the friction between the plant mass and threshing unit.

$$Pt = f\,P \qquad (12.6)$$

Where, f, coefficient of friction.

The value of f for the rasp bar cylinder is 0.65 – 0.75 and for the peg type cylinder the value is 0.7 to 0.80.

Substituting the values,

$$\begin{aligned} P &= Pi + Pt \qquad (12.7)\\ &= m\,(U2-U1) + f\,P \\ &= m\,(U2 - U1)/\,(1- f) \end{aligned}$$

Multiplying both sides with the peripheral velocity by U the power required for threshing (NT) is

$$NT = m\,(U2-U1) \times U\ /\ (1-f) \qquad (12.8)$$

The power required overcoming friction of bearings and air resistance is given by

$$NA = A\,V + B\,V^3 \qquad (12.9)$$

Where A and B are the coefficient of friction and air resistance of the threshing cylinder due to rotation.

For the threshing cylinder with pegs, the value of A = 5.0 to 5.5 N and, for the rasp bar cylinder A, 0.85 to 0.9 N, Where N, Newton.

The weight of threshing drums used on wheat threshers may be around 100 kg.

The coefficient B of the relation represents

the air resistance, which depends on the geometry of the rotating parts of the cylinder and also the air.

The value for the 1 m long threshing cylinder are reported as 0.045 N sec^2 / m^2 for the peg type cylinder and 0.065 N sec^2/m^2 for the rasp bar cylinder.

Therefore, the total power input to the threshing cylinder is

$$PiN = NT + NA$$

$$= \frac{m\,(U2-U1) \times V}{1-f} + A\,V + B\,V^3 \qquad (12.10)$$

If the power of the power source is PsN which is to be transmitted to thresher at the speed of np rpm, the value of PsN governs the operating conditions of the cylinder i.e. if PsN <PiN the speed will fall and if PsN > PiN the speed of cylinder will increase.

$$(PsN - PiN) = I.r.\omega.\ d\omega/dt \qquad (12.11)$$

Where, I. r = moment of inertia of rotating mass of the threshing cylinder unit.

Therefore, the change in speed will be given by following relationship

$$d\omega/dt = [Ps\,N - \{(U2 - U1) / (1\text{-}f)\} \times m\,V - AV - BV^3] \times 1/I.\ r \times \omega \qquad (12.12)$$

The above equation is the basic expression for the operation of the cross flow-threshing unit. It combines the three constituents of the threshing process, the plant mass, its coefficient of friction f, the threshing drum (I.r) the mass moment of inertia and angular velocity and the speed of power source V.

The relationship indicates that the angular acceleration is the function of feed rate m for the various values of V and (I. r). Thus the change in feed rate dm is far more rapid for cylinder of small moment of inertia. Thus it is advisable to have cylinders of large moment of inertia. Some of the thresher manufacturers install the fly wheel to increase the moment of inertia.

Further cylinder operating at low speeds accelerates less rapidly than those working at high speed for the given change in feed rate. Thus threshing cylinders working at low speeds have a greater threshing capacity. In cross flow threshers the thresher cylinder diameter varies from 445 to 610 mm for the peg and rasp bar type cylinders.

The numbers of rasp bars or spike tooth bars provided are four to eight. The threshing capacity depends upon the length of the rasp bars. The experiments conducted on wheat crop having moisture content in the range of 14-18% and grain weight of 36 to 40% of the plant material one can successfully use feed rate in the range of 0.3 to 0.45 kg/s/m when the drum diameter was 550 mm.

Peg tooth cylinder of rice thresher: The feed rate is directly proportional to the number of teeth or pegs and the permissible feed rate per tooth.

$$m = m\acute{o} \times z \qquad (12.13)$$

m, allowable feed rate for threshing cylinder of peg type

mó, permissible feed rate for one tooth which is 0.025 to 0.04 kg/sec/tooth

z, no of teeth on the cylinder.

The number of teeth on cylinder also depends upon the length of cylinder

$$z = mp\,(lw\ /a + 1) \qquad (12.14)$$

Where, lw, working length/width of the cylinder,

a, distance between adjustment path of teeth, the value of

a, 25 to 30 mm, and,

mp, number of pitches of helix over which the teeth are located.

The value of mp is equal to half the number of cross bars where teeth are placed at the points of intersection of the helical lines and the cross bars when the cylinder rotates each tooth moves in perpendicular plane.

Therefore, the numbers of adjacent planes in which teeth move are:

$$p = lw\ /a + 1 \qquad (12.15)$$

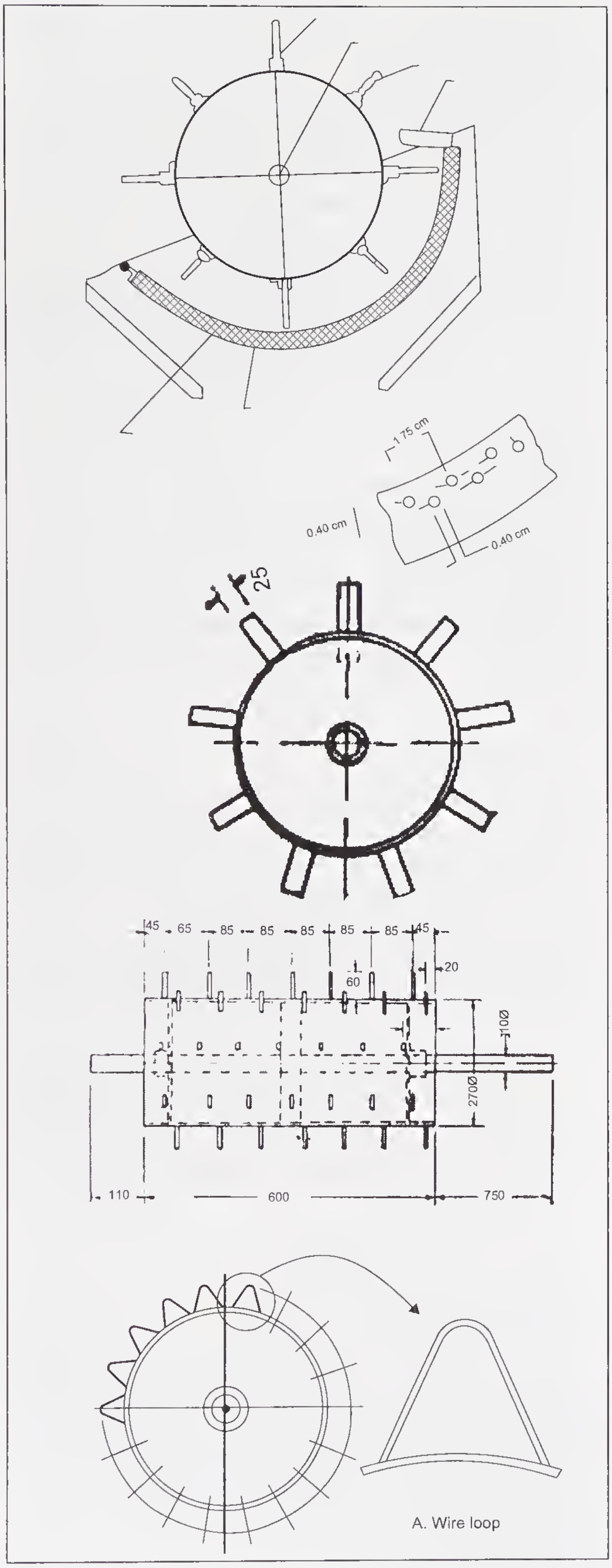


Fig. 12.17. Threshing cylinders with peg type and wire loop teeth arrangements.

The number of rows of spikes used varies from six to eight on rotating threshing cylinders used for rice and wheat crops. Eight rows of spikes are widely used. The studies have also shown that the open type-threshing cylinder is better as compared to the closed cylinder. When the rows of spikes are mounted on the periphery of rings or discs it is called the open type cylinder, when the spikes are mounted on drum of sheet it is called closed cylinder.

The grain output for the small thresher for rice crop per person was approximately 30 to 50 kg and that for the pedal operated machine was 34.5 kg (Table 12.7). The output per hp of power source was within 50 to 60 kg of grain/h for the conventional machines tested during 1968. Sakun (1963) had reported that the wire loop type cylinders have high threshing efficiency and performance and used 23.4% less fuel than rasp bar type cylinders. The rasp bar cylinder also caused more damage as compared to wire loop cylinders.

Sarwar and Khan (1987) studied the performance of rasp bar and wire loop type threshing cylinder for rice crop in terms of cylinder speed, concave clearance, feed rate, grain moisture content. The identical cylinders were 444.5 mm diameter and 508 mm long. The rasp bar cylinder had four rows or bars and wire loop cylinder was fitted with 47.3 mm loops at 51 mm spacing on the rows. The test set up was operated by 10 hp motor. The crop selected was at two moisture levels 16 and 24% on wet basis. The concave clearances were 3.1, 6.3, and 9.5 mm and feed rates were 120 g/s and 240 g/s (equal to 432 and 864 kg of crop per hour). It was concluded that rice at 24% moisture level (w.b) the performance at low concave clearances and low feed rate, was not different but at 9.5 mm clearance the wire loop gave better performance. At higher feed rate also the performance was better at speeds from 13.66 to 18.63 m/sec. No grain damage was noticed for wire loop teeth up to 18.63 m/sec ecspeeds. In case of rasp bar the damage started at 13.97 m/sec at 3.1 and

Table 12.7. Comparative performances of selected rice threshers evaluated at IRRI Los Banos, Laguna (1968).

Thresher model	Machine perfor-mance kg/h	Power performance		Labour performance			Economic performance	
		Engine Hp-h	Hp per 44kg	No of men	Man-h per ha	Grain output per man-h (kg)	Machine cost	Threshing cost per 44kg (Pesos)
Pedal thresher wire loop type local make	68.64			2	128.2	34.32	NA	
Single drum wire loop local make	158.40	4.0	1.333	3	83.33	52.80	2,464	0.930
IRRI drum type wire loop	252.12	4.2	0.695	5	87.26	50.42	3,000	1.06
IRRI table type wire loop	228.80	4.2	0.807	5	96.17	45.76	2,500	0.912
Japanese automatic wire loop	195.36	4.2	0.946	3	67.56	65.12	3,500	0.765
Drum type locally make spike tooth	117.04	12.5	4.700	4	172.94	29.26	6,750	1.512
Vogel nursery spike tooth	126.72	10.0	3.473	4	138.81	31.68	NA	
Turner economy rasp bar type	170.72	10.0	2.577	4	120.00	39.60	NA	
Garvie type DA rasp bar	163.24	17.5	4.717	4	107.85	40.79	NA	

6.3 mm clearances. At 9.5 mm clearance the seed damage started at 18.63 m/sec speed. For threshing wire loop threshing cylinder was considered more compatible.

The tests on combine harvesters had also indicated that the permissible feed rate for cereal crops containing 35 to 40% grain and at moisture level of 14 to 18% for drum diameter of 550 mm the feed rates are 0.35 to 0.4 kg/sec-min. This is equal to feed rate of 1,440 kg/h of crop for the threshing cylinder of 1 m length.

However, in case of paddy threshing with IRRI axial flow thresher the energy input is less than 6 kWh per tonne of grain output. This is because of easy to strip the grains from plant material due to axial flow of crop through the threshing unit. Here the crop is subjected to impact forces of threshing drum and material is turned a few times inside the unit to separate the grain from the straw mat. Hence the output of paddy grain was reported as 500 kg/h for the 3.0 kW energy input. Hence energy requirement for crops vary according to the type of crop, its variety and the moisture content, therefore, the output of threshers vary from crop to crop.

Length of cylinder for Japanese type threshers: In case of rice threshers developed in Japan, the crop is fed as hold on type method, the width of cylinder is based on the number of persons required to feed the crop to the machine as reported in Japanese literature. This concept is widely used on threshers manufactured in Japanese and Republic of South Korea. When one person is required to operate the thresher the recommended length of threshing drum is 450 mm for stripping type paddy thresher. For two operators/workers the width of cylinder is 600 mm and for three persons the width selected

is 750 mm or more. In automatic rice threshers the material to be fed by the crop conveyor and the speed of conveyor is so adjusted so that the crop gets sufficient time to remain in contact with drum to get all the grains detached from the ears. The speed of conveyor is normally set at 0.25 m/sec; and the cylinder width for this is in the range of 600 mm.

Power requirements for low capacity wheat threshers: In wheat threshing units developed, the knowledge about energy consumption to thresh the amount of crops can be used. The energy consumption recommended by Bureau of Indian standards was reported as 85 kg of grain per kWh of energy for the wheat threshers which are required to make bruised straw (*bhusa*) also. Thus thresher operated by a 3.0 kW motor should give the grain output of 85 x3= 250 kg/h.

The details of operational settings for spike tooth cylinders for threshing of various crops as determined at CIAE, Bhopal during 1978-1998 are given in Table 12.8.

The power requirements of the spike tooth type (PUSA-40) threshers on wheat crop were studied and reported by Sharma and Sirohi 1984. It shows that as speed of drum was increased the threshing efficiency increased along with cleaning efficiency. The grain losses were 4% per cent.

The energy requirements for the spike tooth type thresher for wheat crop were determined. Fig. 12.17, and 12.18. It was reported as 1.3 hp-h per quintal of grain by Gupta *et al.* (1986). He measured the power consumption with energy meter and thresher

Table 12.8. Peripheral speeds and operational settings of spike tooth cylinder type thresher recommended by CIAE Bhopal (*Source*: Majumdar, 2001)

Crops	Threshing parameters						
	Cylinder speed (m/sec)	Aspirator blower speed (m/sec)	Concave clearance (mm)	Gap between two bars of concave (mm)	Sieve shaker stroke length (mm)	Sieve hole size (mm)	Sieve slope (degrees)
Cereals							
Wheat	21	30	10-15	7	24-28	5	1.0-2.5
Paddy	16	30	15-25	9	24-28	8	1.5-3.0
Sorghum	11	30	15-20	9	26-30	8	1.5-2.5
Maize	9	30	20-25	25	26-30	12	2.0-3.5
Pulses							
Gram	11	34	15-20	9	26-30	8	2.0-3.5
Lentil	9	26	10-15	7	24-28	5	2.5
Green gram	9	30	10-15	7	--	5	-
Pigeon pea	7	30	15-20	7	24-28	8	2.0-2.5
Oilseeds							
Linseed	16	26	10-15	7	24-28	5	1.5-2.5
Sunflower	11	26	20-25	25	26-30	8	2.0-2.5
Safflower	11	26	15-20	7	24-28	8	1.5-2.5
Mustard	9	26	10-15	7	24-28	5	1.5-2.5
Groundnut	9	-	20-25	25	-	18x45	-
Soybean	7	34	15-20	9	26-30	9	3.0-4.0
Castor	5	-	15-20	9	-	9	-

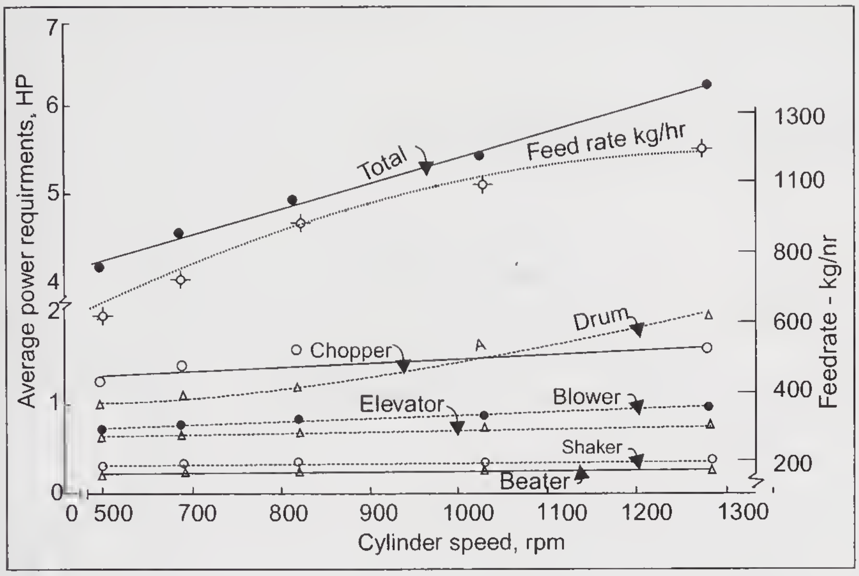


Fig. 12.18. Variation of power requirements with respect to cylinder speed and feed rates of Pusa -40 thresher (*Source:* Sharma and Sirohi 1984).

was fitted with electric motor. The specific power requirement of threshing cylinder, blower and the cleaning sieves were in the range of 0.657-1.089 kWh per quintal of grain output, 0.181-0.657 kWh and 0.0049-0.025kWh for the blower and sieves respectively. The power requirement for the sieves was 0.044 kW at 750 rpm and it increased to 0.1148 kW at 890 rpm and to 0.148 kW at 1,030 rpm as the feed rate was increased from 3 to 10 q/h.

The power requirements were also measured at no load. The power requirements for the blower remained nearly constant for the feed rate studied. The power requirements for the cleaning sieves did not show appreciable increase. The power requirements for the cylinder showed increase with increase in feed rate (Fig. 12.19).

The specific power requirement of threshing cylinder either increased or remained at a minimum value at intermediate feed rate. It then increased as the feed rate was increased. As the speed of thresher was increased from 750 to 1,030 the power requirements increased by 50%. The specific power verses different feed rates are shown in Fig. 12.19. It was concluded that threshing cylinder consumed the maximum power (55-82%) followed by blower (17-43%) and sieves (0.4-1.7%). To reduce the power consumption slower speeds (700-750) of operation were suggested for the cylinder and blower. From these data it was concluded that a 3.75kW powered thresher would give an output of 240-275kg/h in wheat. The grain output for the paddy crop would be more and it has been reported as 400-500 kg/h.

The thresher output is very much affected by the crop characteristics. The important parameters reported are the moisture content and the per cent of grain in the crop mass. The threshing of crop is easy when it is dry. The bulkiness of straw affects the output of the thresher as in mustard crop. The density of grain influences the output of thresher. In crops with low bulk density the output is low, this has been noted in case of threshing of sunflower crop. For high yielding varieties, normally the straw amount is less and the amount of grain is more but in traditional varieties of rice and wheat, normally the straw is long and grain percentage is less.

Flywheel size: On wheat threshers in India, flywheels are mounted to provide uniform energy for threshing with least fluctuation of motor speed. This is necessary to maintain uniform speed even if the feed rates are variable due to manual feeding of crop in thresher. The flywheel acts as the reservoir of energy to overcome fluctuations in the speed during operation. To provide the input data on the flywheel for power threshers detailed specification and information of flywheel of 2.2 to 15 kW size threshers manufactured in Madhya Pradesh were collected. Based on the survey data and observations made at CIAE Bhopal, the sizes of different flywheels are given in the Table 12.8. The analysis of data

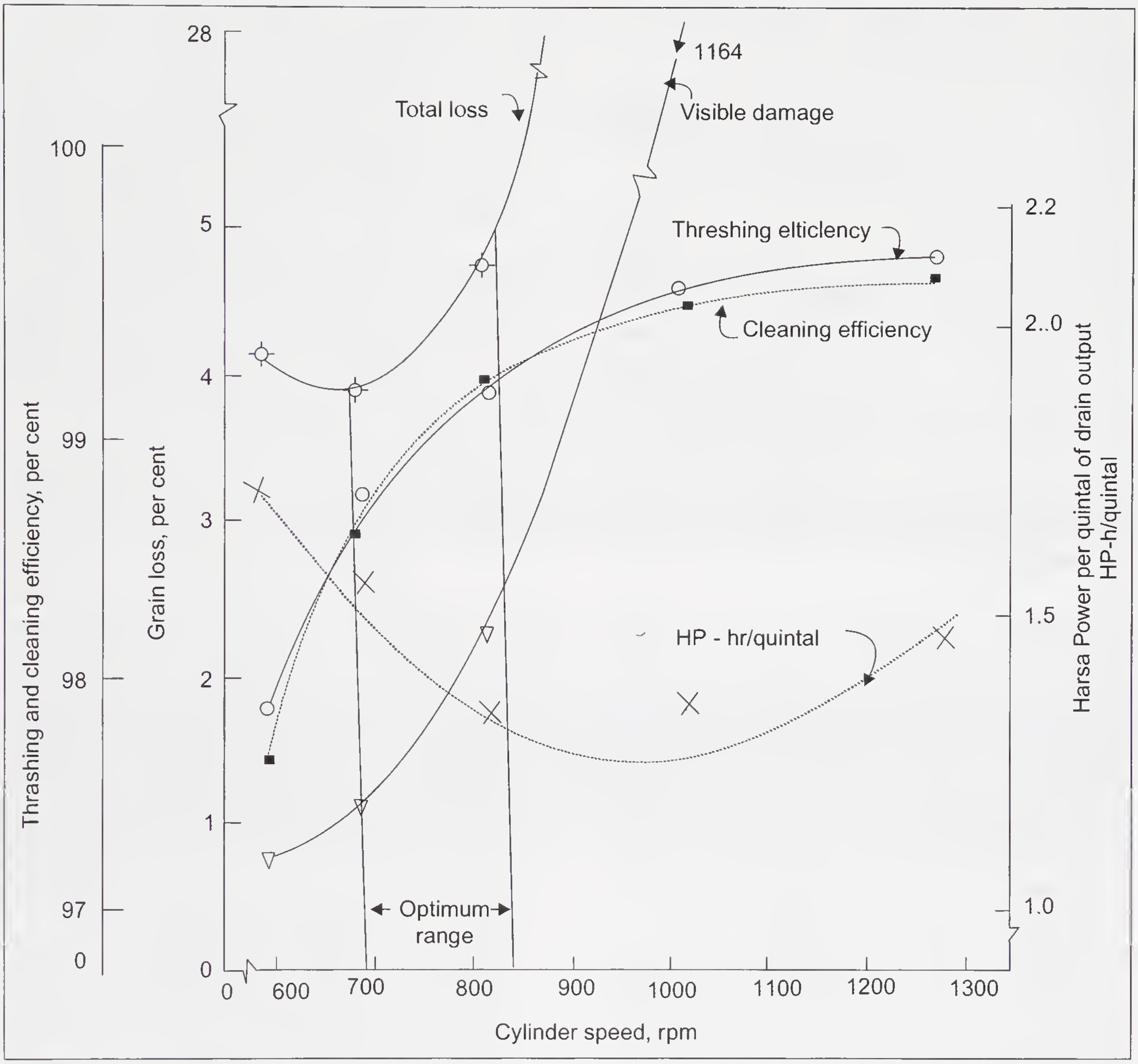


Fig. 12.19. Threshing performance curves with respect to cylinder speed for Pusa 40 thresher.

indicated the fact that the moment of inertia of 9.0 to 11.5 N m² is required for each kW of power unit of thresher.

Other dimensions of cylinders: Banga (1981) studied the performance parameters of spike tooth threshers to analyze the effect of design features of threshing cylinder on threshing of wheat crop. He reported a number of relationships for the spike tooth cylinders for wheat threshers as follows:

(i) $\dfrac{\text{Cross sectional area of spikes}}{(\text{Width of cylinder})^2} = \dfrac{2{,}535}{1000}$

(ii) $\dfrac{\text{Length of spike}}{(\text{Dia. of cylinder})} = 0.25$

(iii) $\dfrac{\text{Axial distance between spikes}}{\text{Width of cylinder}} = 0.11$

(iv) Peripheral spacing between spike rows = 36 to 40 degrees

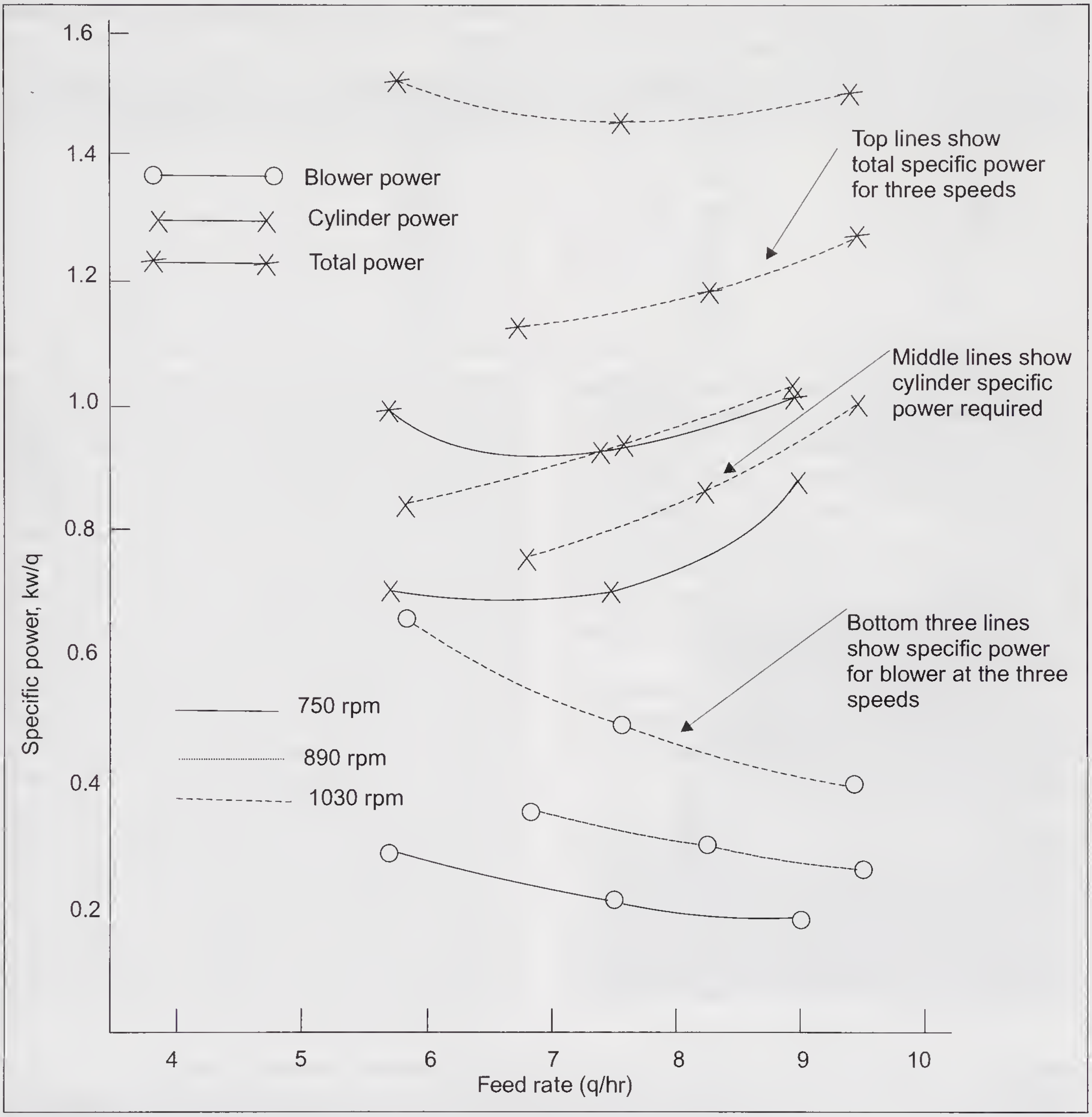


Fig. 12.20. Specific power requirements of different components of spike tooth wheat thresher at different feed rates and cylinder speeds (*Source:* Sharma *et al.* 1986).

(v) $\dfrac{\text{Width of cylinder}}{\text{Diameter of cylinder}} = 0.7$

(vi) $\dfrac{\text{Characteristic length of grain}}{\text{Tangential distance between concave bars}} = 0.42$

(vii) $\dfrac{\text{Cylinder concave clearance}}{\text{Mean diameter of straw stems}} = 4$

(viii) $\dfrac{\text{Spacing between bars in upper concave}}{\text{Thickness of bars}} = 12$

Table 12.9. Recommended weight, mean diameter and moment of inertia of the flywheel used on the power thresher in India of spike tooth type (*Source:* Majumdar, 2004).

Power, kW	Weight of flywheel, N	Mean diameter of flywheel, mm	Moment of inertia of flywheel, N m^2
2.2	250	550	20
3.7	400	600	37
5.6	650	600	58
7.5	650	700	81
9.3	850	700	105
11.2	900	760	126
15.0	1150	760	170

From these relationships the threshing cylinder dimensions can be determined which are not designed theoretically.

The tests conducted at CIAE, Bhopal on threshers with different crops using spike tooth cylinders have yielded the following information on the design of threshing area and concave opening area on the basis of feed rate. In these threshers the concave grate covers the cylinder by 180 degrees.

Using this information one can decide the area of concave for the threshing unit. This also helps in deciding the size of sieves to be used on the cleaning unit.

Details of threshing drum of spike tooth type

The spike tooth cylinder design takes into account the crops to be threshed with the unit. It should be strong and sturdy, and well balanced. The cylinders are made as closed or open type. In open type cylinder, it is made of two to four steel rings made from 8 to 10 mm thick flat of 50 mm width. At the centre of rings the bushes are welded and spokes are welded to join ring with the bushes. The shaft size used on wheat thresher is of 45 mm diameter. These rings are fixed on the shaft of the thresher. The spikes are round bars of 12 mm in diameter and of sufficient length, and its lower portion being threaded. In some designs the top round portion is flattened by hot forging process to make flat teeth type spikes. The holes are made on the flat bars on which the teeth are mounted in staggered manner. These flats with spike tooth mounted on them are bolted to the cylinder rings as per designs to make the threshing cylinder (Fig.12.21B). The details of three threshing cylinders designs used are shown in Fig.12.21 A, B and C for wheat, and multicrop threshers and rice. The fabrication of cylinder is mostly made from hot rolled

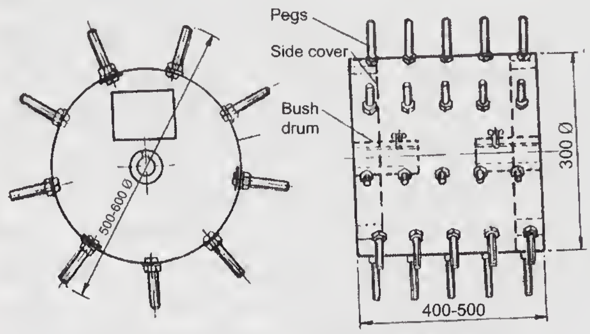
Table 12.10. Threshing system dimensions used on multicrop stationary threshers in India

Thresher size	Power source kW	Threshing area per kg of feed rate in cm^2	Concave opening area per kg of feed rate in cm^2	Sieve perforation area per kg of feed rate, cm^2
Spike tooth cylinder 5 hp size	3.7	10	3.0	0.71
3 hp size	2.6	8.6	4.0	0.59
Spike tooth cylinder,5 hp size	3.7	8.8	2.50	0.62
CIAE multicrop thresher	3.7	9.9	3.8	0.70
CIAE axial flow Multicrop	5.6	9.9	4.0	0.80
Recommended values	Up to 5.7kW	9.5	3.50	0.70

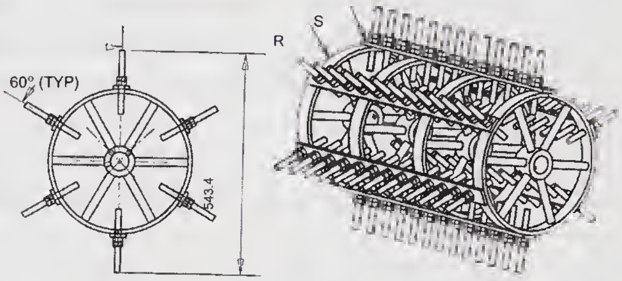
mild steel sections. The cylinders used on wheat threshers are of heavier type as they are used to break up the wheat straw completely.

The cylinders used on rice thresher are of lighter type as they are used to strip the grain of the straw mass. In axial flow threshers the crop is fed completely in the threshing unit and the straw after threshing action is moved out of machine axially at the other end (Fig.12.21 C). Thus the threshing cylinder is of medium weight. This design has the unique features of louvers in the top cover of the threshing drum.

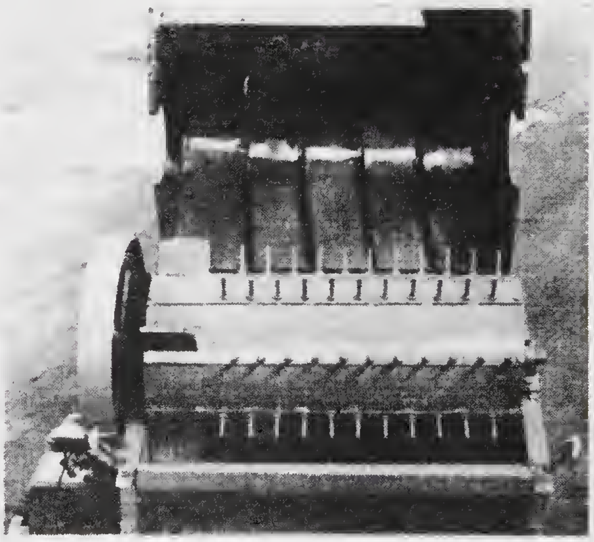
The number of bars and width in case of open type cylinder can be adjusted to desired width by fixing the number of rings. The teeth length and number can be adjusted to increase or decrease cylinder clearance (Fig12.21 B). In place of teeth the straw throwing paddles can be fixed at the outer end to throw out the straw when such a cylinder is used as axial flow type unit. The teeth are bolted on the bars with lock nuts. The teeth can be repaired easily. Cylinder of such design are mostly used for wheat threshers. In case of rice crop the spike teeth are of small diameter (8-10mm). The rings are made lighter in section. The unit is mostly mounted on 45mm diameter shaft in wheat threshers. For rice threshers 35 mm shaft diameter is adequate. Thus cylinders of different sizes and dimensions can be produced in small workshops. The design of spike tooth cylinder, the main emphasis is that cylinder should have long operating life. It should be light but strong enough for handling crop materials and maintaining good balance during operation. The cylinder is made up of steel rings using 8 to 10 mm thick flats. The bushes are welded at the centre of rings for mounting and fixing it on the drive shaft. The spikes are bolted and welded on the flat bars. The spike pegs are staggered so that they have different path of rotation and loaded uniformly. The spikes are bolted on the bars with double nuts or locknuts to prevent their loosening during operation. Using the steel scale or flat surface all the spikes are adjusted for the same length before mounting on the cylinder shaft. The hubs are bolted with threaded bolts and lock nuts.



(A) Spike tooth drum of closed type for wheat



(B) Spike tooth drum of open type for multicrop



(C) Axial flow threshing cylinder for threshing rice with louvers in top cover (IRRI Thresher).

Fig. 12.21 (A-C). Details of spike tooth drums of open and closed type.

Design of concave

The concave used on threshers for wheat crop or axial threshers for paddy crops are made as grates from the mild steel bars of

round or square size 6-8mm. The concave grate bars are spaced by the distance equal to or more than the characteristic length or dimension of the grain. For the paddy the spacing between two wires is normally 9 to 12 mm and in wheat the space is kept as 6-7 mm. For chickpea, soybean, the gap recommended is 9 mm. While threshing maize and sunflower the gap between bars is maintained between 22-25 mm. Therefore for the CIAE multicrop thresher three concaves were provided with spacing between bars as 7, 9 and 25 mm. These three concaves take care of most of the crops to be threshed by farmers.

In paddy threshers of hold on type machines, the concave provided is of wire mesh type with 8 to 10 mm square opening size. This is claimed to be more effective compared to screens with round holes of 9 or 10 mm diameter sizes. When screens are used, the time taken by the material to pass through is more and, therefore, the wire mesh type concave is preferred.

The gap or clearance between cylinder and concave is made adjustable if the threshers are multicrop type. For example the gap of 6 mm is sufficient to thresh the wheat crop and bruise the wheat straw. But for threshing soybean the clearance has to be increased to 11 mm to avoid the grain damage. For threshing maize the clearance required is 20 mm to allow the crop to be threshed easily. The clearance depends upon the size of grain and in throw-in- type machine the diameter of crop stems is also considered. Thus based on above information and as reported in Table 12.8 for different crops, the concave is designed.

The thresher concaves are made from mild steel rods, which are welded, to side plate or the flats of semi circular shape. The concave rods are welded at equal spacing of 8 mm or 10 mm depending upon the crop requirements. The spacing between rods for rice crop is 10 mm and for wheat it is 6 mm. The grate is made of 6 mm rods and they are reinforced depending upon the width of the concave. A simple jig or fixture is made to make the concave of desired shape without any wrap due to welding of parts of concave. In concaves the crop inlet portion is made blank so that the proper beating action by beaters takes place to push the grain out of ears. Sometimes long blanking strips are fitted to achieve this action where crop conditions demand blanking of concaves. The axial flow thresher when used for threshing crop where straw is to be broken up the stripping bars are mounted at the rear end of concave. In threshing of ears of sorghum crop the blanking and stripping bars are used to thrash the grain out of ears without having spikelet's mixed in the grain. A few types of concaves used on the thresher are shown in Fig.12.22 and 12.23. For threshing of groundnut crop, the concave grate size is with large openings to allow the pods to drop

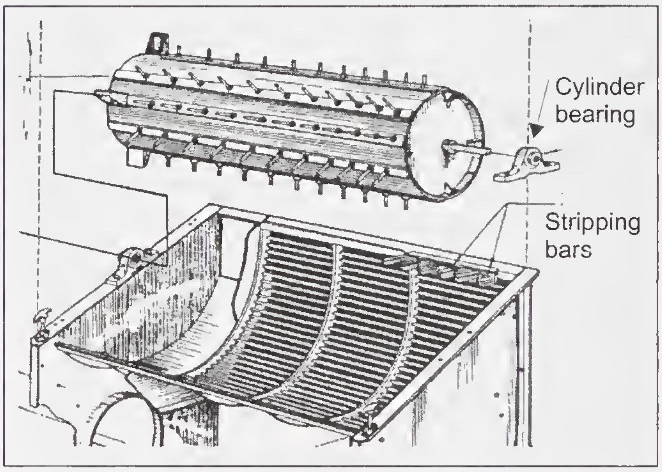


Fig. 12.22. Details of concave used on rice thresher of axial flow type (IRRI).

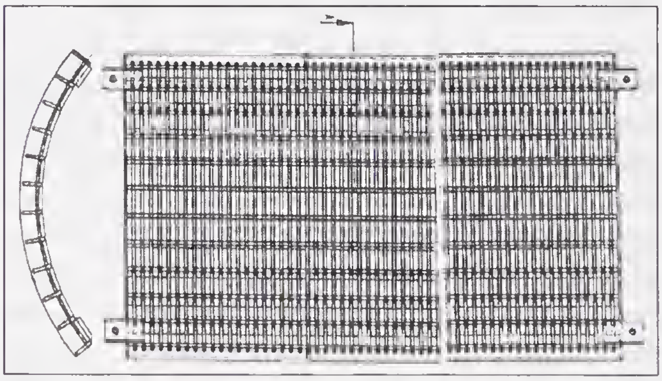


Fig. 12.23. Concave used for threshing pigeon pea (CIAE, Bhopal).

through it. The grates size of 40 × 30 mm or more is generally provided.

High capacity threshing units (1.0 tonne/h)

CIAE, Bhopal developed a high capacity thresher of multicrop type based on principle of spike tooth cylinder during 1994-95. The machine was to produce the tenderized straw to be used as animal feed on the farms. Thus the thresher was for crops like sunflower, soybean, gram, wheat, maize and sorghum. All these crops are grown in Central India and are harvested by the farmers at low moisture level of 10% . The aim was to encourage the owners to do custom work of threshing in their villages. In this thresher the drum size selected was 700 mm diameter and 1,100 mm width. It was fitted with hopper into which crop bundles can be thrown into for threshing. As the machine was tractor operated it had enough power to thresh the crop without getting choked. The thresher was provided with three set of concaves with 7, 9 and 25 mm openings for the different crops. The cleaning was achieved by aspiratory type blowers. As the thresher has to handle crop quantities above 2-3 tonnes/h, the three blowers were provided to aspirate the light straw material. The unit had also bagging arrangement. The performance data indicated that it gave an output of 553, 872, 1,225, 1,340, 3,010 kg/h for sunflower, soybean, gram, wheat, maize and sorghum crops respectively with losses between 1 to 3%.

In axial flow type threshing cylinder of high capacity machine used for threshing the rice and pulses, the length of cylinder is increased to include the crop feeding zone, the threshing zone and separation of grain from the straw zone, along the length of cylinder. Therefore, length of cylinder is kept large. Normally the material is given three to four revolutions before it is thrown out of the threshing unit. This is achieved by providing louvers in the top of the casing of the thresher. The studies in India indicated that the minimum length of drum for threshing should be 300 mm for the separation of grain from straw of the crop. Hence cylinder length of 600-800 mm is to be used on the small size threshers (300-400kg/h). When the thresher is to be designed for high capacity the feed inlet, threshing and separation zones are to be increased to achieve complete threshing and separation of grain. For high capacity threshers developed in Thailand the length of cylinder is around 1,000 mm. The diameter is 350-400 mm and speed of operation is 500-650 rpm. With the axial flow thresher, crops like rice, soybean and moong beans (green gram) are threshed. The units are powered with diesel engine of 10 hp size.

Ultra high capacity threshing units (feed rates up to 7.0kg/sec)

The axial flow threshing is most suitable for use on the combine harvesters to overcome the problem of sifting of grain at the threshing level when combines are supposed to handle the crop feed rates of 20-25 tonnes/h due to introduction of high yielding varieties of wheat etc. The principles of axial flow threshing units have been reported in Europe by a number of research workers. The results of experiments conducted have shown the complete threshing and separation with the minimum of losses. The Fig. 12.24 gives the relationship of cylinder length verses performance parameters such as, the unthreshed grain, threshed grain (free grain), cumulative separated grain and the frequency of separated grain for the axial flow rotor used on the combine harvester.

The rotor length of 2.0 m was reported to recover the grain completely which is separated by the threshing action. This information is reported only for research workers as such high capacity machines can only be used on a large scale farms, this is not possible at least in most of the Asian and developing countries.

The mathematical model, for axial flow threshing unit were developed by Miu *et al.*

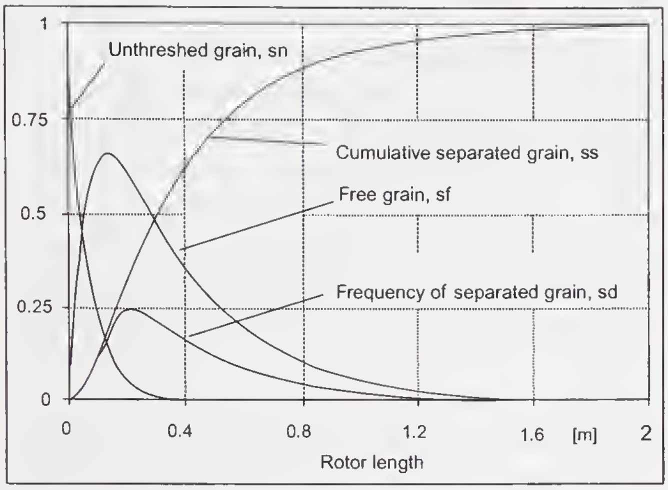


Fig. 12.24. Theoretical performance indices verses rotor length for axial flow threshing unit (Miu *et al.* 1997).

(1997) and were evaluated by conducting laboratory experiments. The experimental setups developed and used are shown in Fig. 12.25 and Fig.12.26 respectively. These are axial flow unit I and axial flow unit II. The units were operated in horizontal plane as well as on incline. The tests were conducted on units, at high feed rates (4.5 to 7 kg/sec up to 25 tonnes/h).

The performance of threshing units of axial flow type for threshing of wheat and other crops was determined. The grain was collected at the collectors placed below the threshing unit as shown in Fig.12.26. The theoretical model developed for axial flow threshing unit

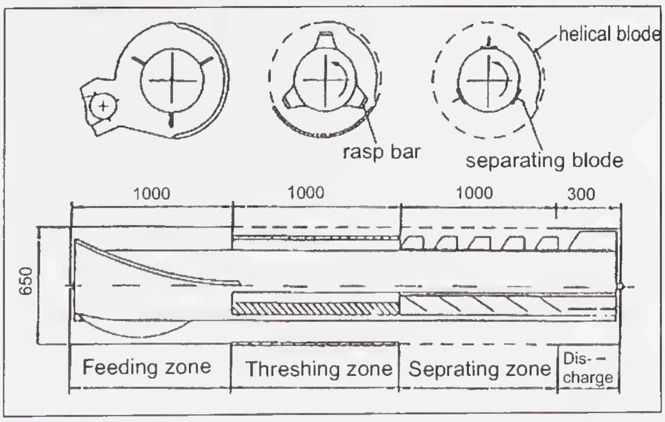


Fig. 12.25. Axial flow threshing test unit I developed for combine. (*Source:* Wacker, 1985).

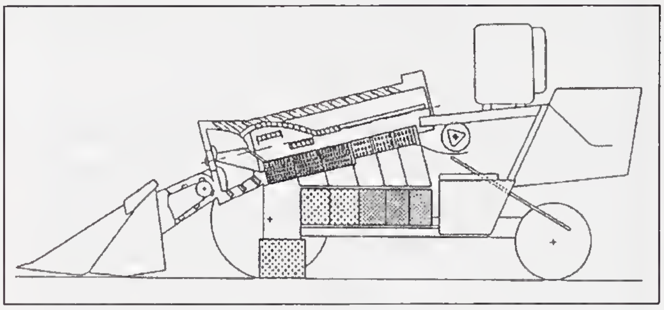


Fig. 12.26. Test unit II of axial flow type for laboratory experiments. (*Source:* Kutzbach and Wacker 1996)

gives the details of performance indices versus the length of rotor used. Thus the theoretical and experimental values were determined for the wheat crop. The performance predicted from theoretical model and experiments are reported in Fig.12.27 for the test set up unit I.

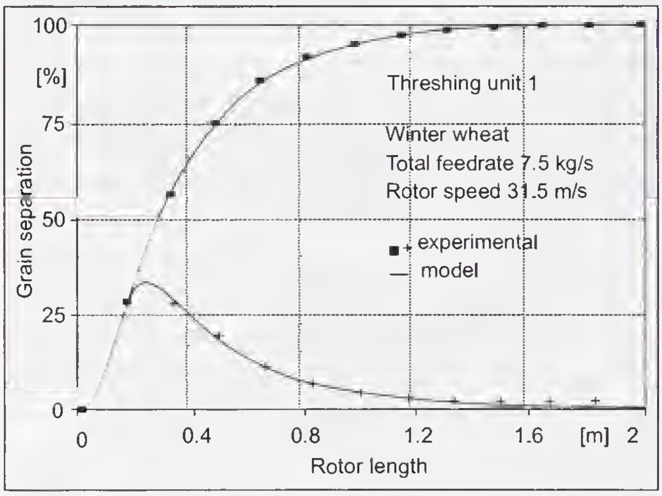


Fig. 12.27. Comparison of measured and predicted grain separation for the different rotor length during threshing of wheat in unit I at feed rate of 7.5 kg/sec.

The Fig.12.28 shows the losses verses the material other than grain feed rate for the test set up. The threshing and separation losses are within 1% for the MOG feed rate of 4.5 kg/sec.

The threshing requirements of crops vary according to the crop to be threshed and the conditions preferred by the farmers to get the clean grain along with straw in fully bruised form or in undamaged or partially broken state. As threshers are used by different category of the farmers (or farm workers) not

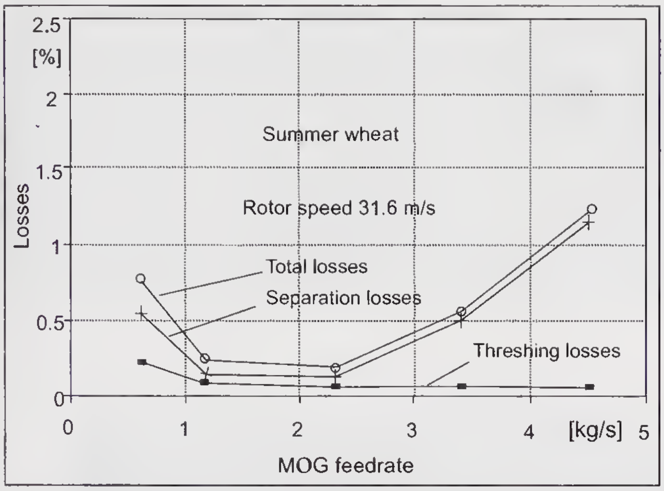


Fig. 12.28. Experimental and model performance values of threshing on winter wheat with feed rate of 4.5 kg/sec on test unit I.

so much educated, therefore, designers should make the thresher suitable for the crops being raised in the areas to make machine useful for them. The rice and wheat are the main cereal crops but their requirements are different. These crops are grown in different seasons. The rice is mostly grown as rainy season crop and wheat is the winter crop. In case of rice crop the simple powered threshing drum can meet the requirements of small farmers. But in wheat even of small farmer would like to have thresher of 3.75kW size, with clean grain and straw in bruising form and with little of grain loss. However the rice wheat thresher of 3.75 kW size would meet the needs of most of the Asian farms. The rains during rice harvest create the problem of threshing of moist crops. Hence axial flow thresher for rice would be required to overcome the problem of threshing the moist crops in such conditions. The same problem can be faced in wheat crop and syndicator type thresher is used by the farmers. The threshing principles described can be used to thresh most of the crop by means of axial flow threshing unit by adjusting the drum speed, blower speed, concave openings and clearances, and sieve sizes to suit the crop. ❑

List of abbreviations

List of abbreviations used in the equations for the design of threshing cylinder are: A, coefficient of friction; B, coefficient of air resistance of the threshing cylinder; mó, permissible feed rate for one tooth which is 0.025– 0.04 kg/s/tooth; z, no of teeth on the cylinder; e, number of teeth depends upon the length of cylinder; l, length of working slit i.e. cylinder length; s, width of working slit in m; γ, bulk density of material in the working slit; c, coefficient of utilization of working slit the value is (0.85- 0.90); N, engine rated power; NA, the power required for overcoming friction of thresher drum and air resistance due to motion; PsN, power of the prime mover; PiN, power input to threshing drum; NT, power required for threshing; m, mass flow rate of crop in kg per second or feed rate; V = peripheral velocity of the cylinder; F, coefficient of resistance of material rubbing in the working slit of drum and concave or the concave clearance; lw, working length of cylinder; s, width of working slit in m; γ, bulk density of material in the working slit; c, coefficient of utilization of working slit the value is (0.85- 0.90); P, Total force applied by cylinder; Pi, impact force; Pt, tangential or pulling force; U1, speed of plant mass before the impact. m/s; U2, speed of plant mass after the impact, m/s; m, the plant mass which receives the impact; I. r, moment of inertia of rotating mass of the threshing cylinder unit; MOG, material other than grain; sn, unthreshed grain; ss, cumulative separated grain at threshing unit; sf, free grain; sd, frequency of separated grain.

13 Design Principles for Cleaning Shoe

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The grains in threshing operation are separated from the chaff, straw, husk etc by the blower and a set of sieves. The light particles are separated by forced-air-draught blower (winnower) or aspiratory blower after the mixture of threshed material falls from the threshing unit on the cleaning shoe. The remaining foreign material which falls on the top screen such as nodes or any other heavy particles of plant stems are separated with the mechanical means or devices such as sieves. This provides the purity of grains to the extent of more than 95-98%. Further cleaning of grains is performed by the help of seed cleaner. The Fig.13.1 gives the details of cleaning shoe of the wheat thresher.

Axial flow rice thresher (Fig.13.2) is developed at IRRI, Philippines. It uses the sieves and blower for winnowing action. Fig.13.3 is the cleaning shoe sectional view of cross flow threshers using sieves and blower used on combines. In all the three units the cleaning efficiency of 98 –99 % is achieved. The cleaning shoe used on Indian wheat thresher has to blow out large amount of bruised straw as compared to the other units. The amount of trash to be removed by the axial flow units is the least among the three units.

In traditional system the farmers performs the winnowing in natural air by dropping grain from a height of 2.0 m and further clean manually by a simple screen to remove dust, dirt and fines. Thus clean grain of 98-99% is obtained. Since the cleaning system is based on air separation and mechanical devices like sieves and their design principles are described in details.

Air separation

The separation of grain from the chaff is based on their aerodynamic properties. In a stream of air the particles are suspended only if drag force Fd acting upon is more than the weight of particle.

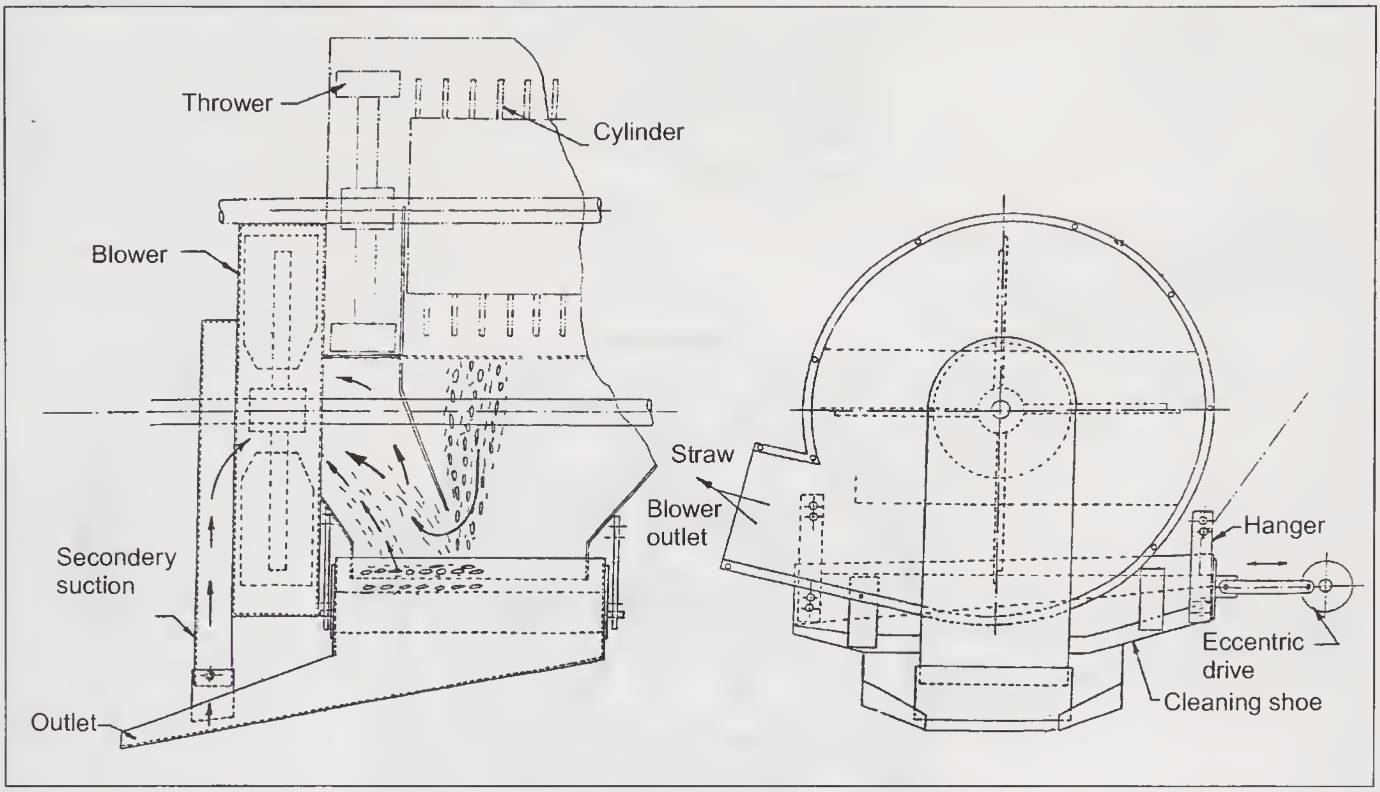


Fig. 13.1. Cleaning shoe portion of aspiratory blower type system of thresher.

$$Fd = \frac{Cd \cdot \rho a \cdot Ap \cdot Vt^2}{2} \qquad (13.1)$$

Where, Fd, drag force; ρa, density of air, kg/m³; Vt, terminal velocity of the particle, m/s; Ap, projected area of particle perpendicular to the direction of motion, m², and; Cd, drag coefficient.

The motion of the particle in a vertical air stream is written as

$$m \times dv/dt = mg - Fd \qquad (13.2)$$

Or,

$$m \times dv/dt = mg - Cr \times V^2 \qquad (13.3)$$

Where, m, mass of particle in kg; g, acceleration due to gravity; Cr, coefficient of resistance, and; V, relative velocity of the particle.

Depending upon the relationship between weight of the particle and the drag force, the Particle will move downward if,

$mg > Fd$ and, move upwards when

$mg < Fd$,

Or remain suspended when

$mg = Fd$ (Fd is the drag force)

The velocity of air stream when the particle remains suspended in the air is known as terminal velocity (Vt). From the above equation it follows,

$$Vt = \frac{\sqrt{2\,Wp}}{\sqrt{(Cd.\rho a.Ap)}} \qquad (13.4)$$

The terminal velocity is influenced by a number of factors. It increases as the weight of particle increases, as in the case of increase or decrease of moisture content of grain or straw assuming the volume of particle of remains constant.

In aerodynamic separation of straw from grain, it is the terminal velocity of mixture, which is exploited for cleaning the grain. Bilanski and Lal (1964) determined the terminal velocity of a few selected particles (Table 13.1). It explains the air velocity for

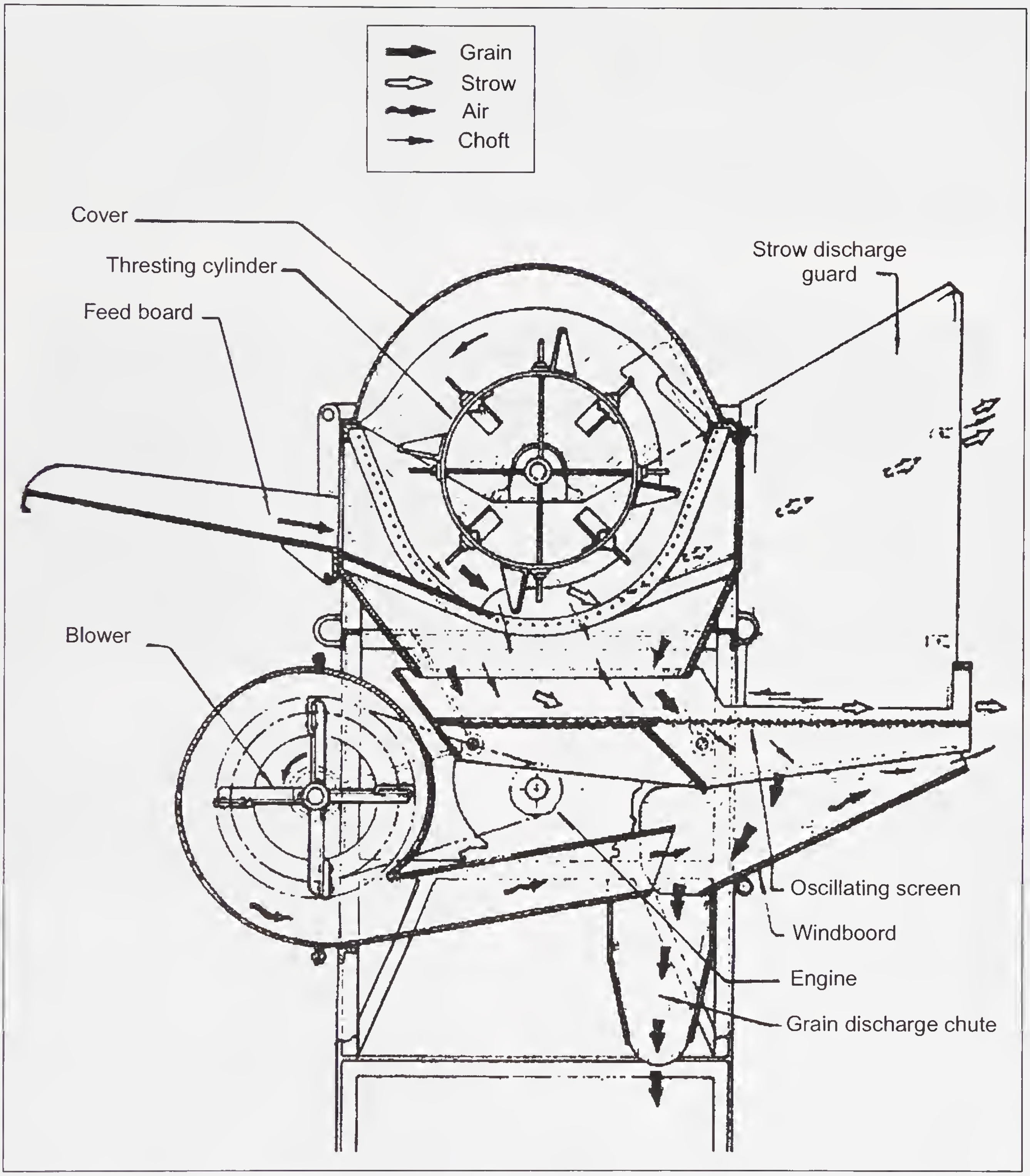


Fig. 13.2. Winnowing type cleaning shoe of IRRI rice threshers.

wheat grains is high as compared to straw or chaff. Thus the terminal velocity for wheat grains of 6-7m/sec would eliminate most of the trash from the grain. Thus for wheat threshers the cleaning efficiency of 99 % are reported by many researchers.

The terminal velocity of straw without node is low even though the length may be more (Fig.13.4). The straw with node at one end has high terminal velocity. Therefore in

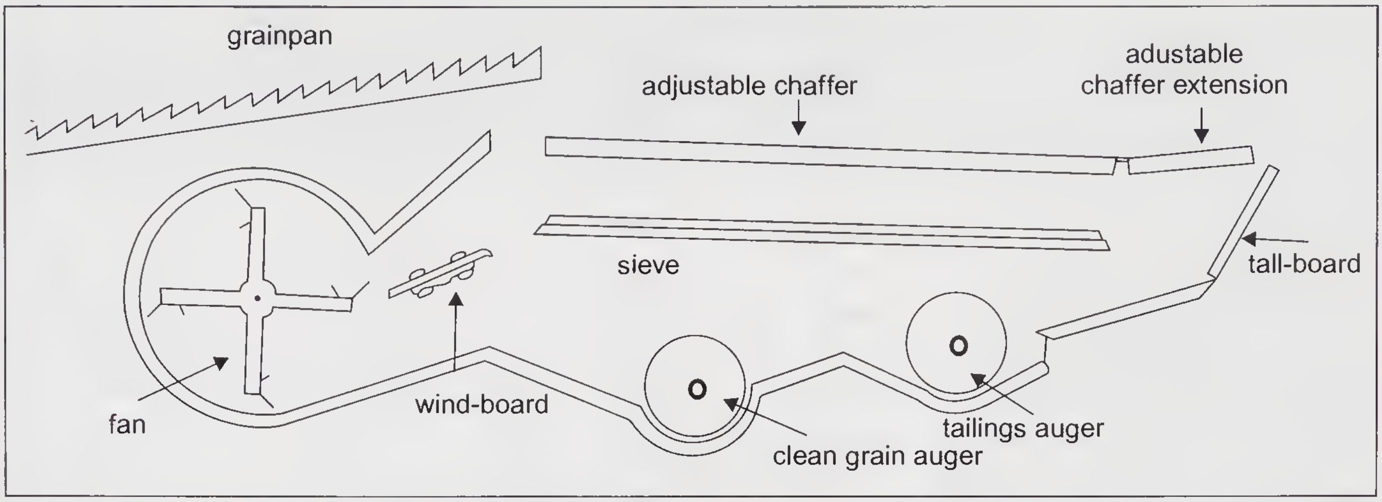


Fig. 13.3. Cleaning shoe used on flow through threshers with straw walkers.

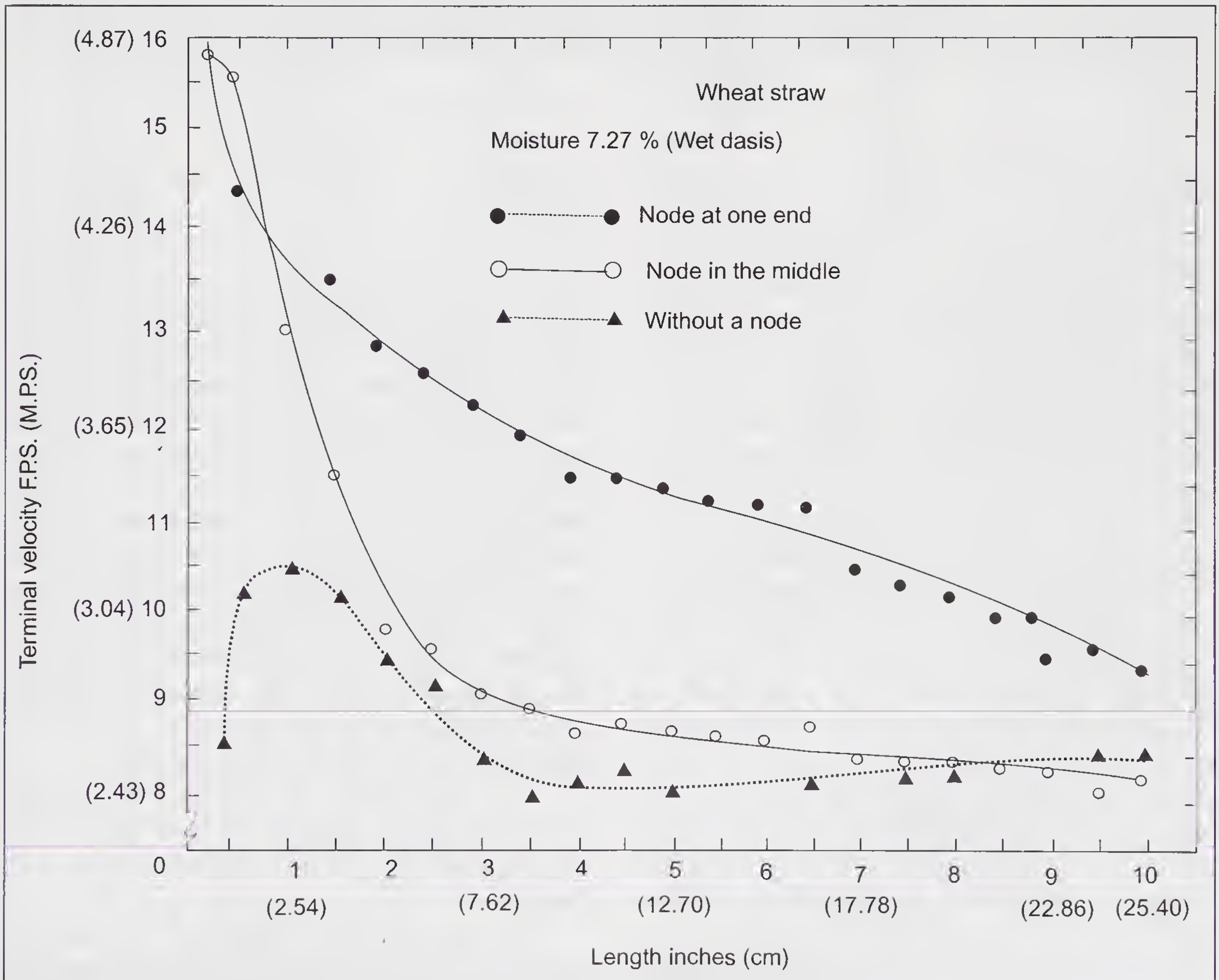


Fig. 13.4. Terminal velocity of wheat straw as affected by its length and nodes.

Table 13.1. Aerodynamic properties of threshed materials (*Source:* Bilanski and Lal, 1964)

Material	Weight W x10 $^{-5}$ lb	Terminal velocity ft/sec	Resistance coefficient K x 10^6 lb-sec^2/ft^2	Drag coefficient C
Wheat chaff	0.7	4.12	0.412	-
Wheat heads	45.01	7.09	8.954	-
Wheat grains	9.3	28.8	0.112	-
1/4-in (6 mm) straw with node	6.52	15.75	0.20	0.84
1-in (25.4 mm) straw with node	11.70	13.0	0.687	0.66
3-in (76 mm) straw with node	24.57	9.0	3.03	0.90
10-in (254 mm) straw with node	74.66	8.25	11.0	0.91

Table 13.2. Range of physical characteristics of grains and air velocity required to airborne (*Source:* Uhl and Lamp, 1966)

Grain	Kernel weight lb x 10^{-6}	Unit density lb/ft^3	Least cross sectional area in^{2}x10^{-4}	Bulk density lb/ft^3	Terminal velocity ft/sec
Wheat	50.84	62.4-77.4	62-91	35.6-49.2	19-30
Rye	39.53	72.4-76.1	51-66	39.3-44.3	20-27
Oats	29.58	46.1-60.5	34-95	23.0-31.8	17-26
Corn	569-692	71.1-74.9	500-610	42.7-46.2	26-42
Soybean	233-419	74.3-72.4	240-470	42.6-43.1	30-60

cleaning shoes of cross flow threshers the heavy chaff particles are blown out. For air separation, the air stream velocity selected is usually 50 % higher than the terminal velocity of the straw or foreign matter. During the motion of the particles in the air stream, they not only move but also spin and rotate about the centre of gravity; they also collide with each other due to spin and turbulence.

The motion of the particles thus becomes difficult to analyze and above equation holds true only partially. Therefore velocity of air during separation should be such that all foreign matter is lifted up but not the grains so as to reduce the blower losses. In other words air velocity should be less than the terminal velocity of grains. In India the wheat thresher bruises the straw and it is aspirated with the paddle blade type of blowers. The size of blower is important to achieve the high cleaning efficiency and minimum of seed loss. Mohsenin (1980) reported the terminal velocity of straw, chaff, and grains is different. The terminal velocities of straw of small and large size are much lower than the wheat grains. The terminal velocity of wheat grains is 8-9 m/sec and most of the straw can be sucked out at lower speeds of 8m/sec. The straw of 12mm –25mm size has terminal velocity half that of wheat grains. Hence the cleaning efficiencies of high values are achieved and are reported for threshers. For small size of straw, the greater is the velocity of air required to lift them. Most of the particles with nodes etc. broken can be lifted with air velocity in the range of 3-6mps. The range of physical characteristics of a few grains were studied and reported by Uhl and Lamp (1960).

For separation of straw from grain, minimum of air velocity of 7 m/sec would be required for wheat, soybean, corn etc. (Fig.13.5)

Table 13.2 shows terminal velocity for soybean was the highest. The size of seed of rye is small but the terminal velocity is slightly less than that of wheat grains.

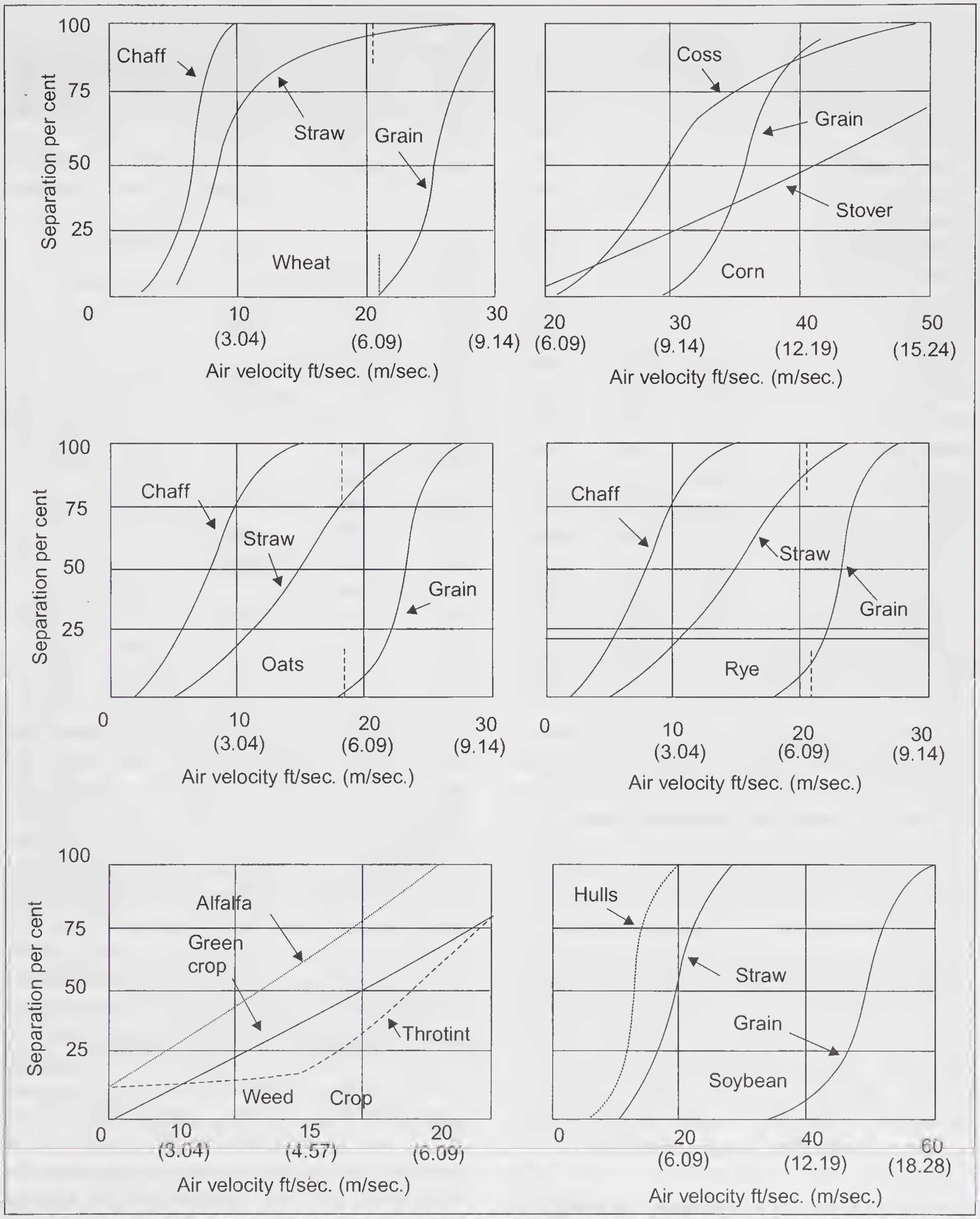


Fig. 13.5. Per cent separation verses air velocity for several grains and associated materials (*Source:* Uhl and Lamp 1966).

Table 13.3 Physical dimensions of a few crop seeds (*Source:* Varshney *et al.* 2004)

Crop	Length	Width (mm)	Thickness (mm)	Sphere-city	Equivalent-diameter (mm)	Bulk den-sity	Specific gravity	Weight of 1,000 grains g
Paddy (IR26)	7.80	2.64	1.90	0.44	3.49	0.547	--	--
Pigeon pea (JA 3)	5.88	5.07	4.23	0.85	5.02		1.34	90.50
Green gram (Pusa 105)	3.82	3.09	2.98	--	3.10	0.740	1.04	35.30
Sunflower var. I	10.6	4.2	2.8	0.47	5.0	0.37	0.6	--
Sunflower var. II	9.3	4.2	3.2	0.53	5.0	--	--	--
Linseed	5.5	2.6	1.2	0.46	2.57	0.64	--	--
Chickpea	7.78	6.30	5.20	0.81	6.34	0.81	--	--
Sorghum	4.75	7.04	2.82	0.77	3.80	--	--	--
Maize	8.67	7.07	5.45	0.80	6.94	0.836	1.41	--
Pearl millet	3.04	2.24	1.88	0.77	2.34	--	--	--
Bengal gram	8.56	6.25	5.96	0.80	6.83	0.783	1.28	206.2
Cowpea	7.83	6.11	4.70	0.77	6.08	--	1.19	152.3
Pea	6.89	6.43	6.04	0.945	6.44	--	--	--
Ground nut kernel (G11)	15.85	7.56	6.84	0.61	9.36	0.593	--	--
Soybean JS2	7.85	7.16	5.89	0.88	6.92	0.684	--	--
Horse gram	5.56	3.85	2.23	0.41	2.56	--	--	--
Castor var. small	9.98	6.85	5.07	0.70	7.02	0.568	--	--
Castor small var. medium	9.98	6.94	5.15	0.71	7.09	0.582	0.89	178.0
Castor medium var. large	17.82	10.23	6.80	0.60	10.78	0.457	0.85	566.5

The point, brought to the notice of thresher designers, is that the blower used on machines should be adjustable for air velocity and the volumes for multicrop threshers because of variation in densities of grains and their shapes etc. The physical characteristics for a few crops are given in Table 13.3. As the air velocities for straw of soybean are 8.2 mps as compared to wheat of 6 mps, therefore the value of cleaning efficiency are affected as the air velocity is not sufficient in case the blower speed is not made adjustable. Mostly the farmers want one machine, which can thresh all the crops without making adjustments and with minimum of grain losses. However the air blast and volume are to be adjusted for proper cleaning.

Design of blower for aspiratory cleaning

The light material during threshing in threshers used in India use the aspiratory blower to suck out the straw and chaff and throw it at a distance for the continuous operation of the machine. In combine harvesters the blower are of winnower type as the machine is moving in the field during the harvesting of the crop and therefore the straw is just blown out of machine while it is falling on the cleaning shoe top screen. Thus the designs of both types of blowers are discussed. In the aspiratory blower the straw is sucked inside the blower, therefore the suction velocity of the air is more than the terminal velocity of straw. The separation of straw from grain depends not only on the ratio between the air velocity and the terminal velocity of the particles but on the quantity of the particles suspended per unit volume of the airflow. When the number of particles entrained in the air stream increases the quality of cleaning

deteriorates because of mutual interaction of the particles. It has been established that the interaction of the particles may be eliminated if they are well dispersed and the distance between them 'c' is greater than 5 times their characteristic dimension'd'. The characteristic dimension of a particle is given by relation

$$d = \sqrt[3]{a \times b \times c} \tag{13.5}$$

Where, a, b, and c are the major, medium and minimum axial dimensions of the particles.

The concentration of straw in the air is characterized by a coefficient 'λ' straw/air ratio, which may be expressed as

$$\lambda = qc \;/\; Qa \tag{13.6}$$

Where, qc, amount of impurities removed during cleaning, kg/sec;
Qa, quantity of air flow through the duct, kg/s

The amount of impurities may be determined from the expression,

$$qc = Qp\;.\;A_d\,.Vp \tag{13.7}$$

where, Qp, quantity of particles per m^3 of air, kg; A_d, cross sectional area of the duct, m^2., and; V_p, velocity of particle through the duct (m/sec).

Assuming that the particles are well dispersed and located at identical distances 'c' in all directions, there are $1/c^3$ particles in one cubic metre of air, therefore for each cubic metre of air

$$Qp = \frac{\Pi \times d^3}{6.c^3} \times \rho_p \tag{13.8}$$

Where, ρ_p, density of impurities in kg/m^3; and d, characteristics dimension of the particle.

Substituting

$$qc = \rho_p \times \Pi / 6 \times (d/c)^3 \times A_d \times V_p \tag{13.9}$$

The quantity of air passing through the duct per unit time is

$$Qa = \rho_a \times A_d \times V_a$$

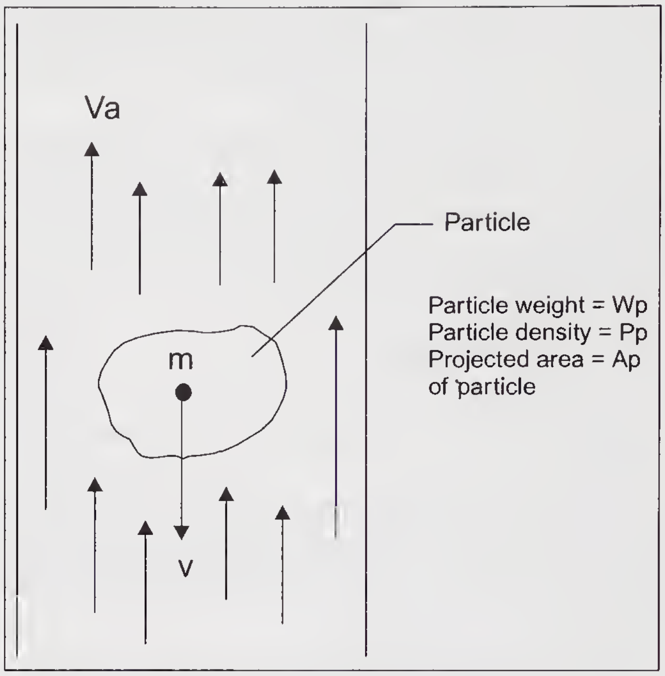


Fig. 13.6. Free body diagram of a particle falling through air stream.

Where, Va, velocity of the air; and ρ_a, density of air.

The concentration of straw in the air is obtained as

$$\lambda = qc / Q_a = \pi/6 \times 1/\varepsilon^3 \times (\rho_p / \rho_a) \times (V_p / V_a) \tag{13.10}$$

Where, ε, c/d;

The velocity of particle, thus is expressed as

$$V_p = \frac{6 \times \lambda \times \varepsilon^3 \times \rho_a \times V_a}{\pi \times \rho_p} \tag{13.11}$$

Assuming that $V_p = V_a - V_t$, thus the optimal velocity of the air in the duct of cross sectional area, A_a

$$V_a = \frac{V_t}{1 - (6 \times \varepsilon^3 \times \rho_a \times \lambda)/\pi \times \rho_p} \tag{13.12}$$

The value of ε varies from 10–16, and the value of λ = 0.025–0.039 for the preliminary cleaning.

For final cleaning depending upon the capacity of cleaning unit and final cleaning

efficiency required, air velocity is determined from the above equation (13.12). The value of λ is 0.14–0.21.

The suction inlet in the case of aspirator blower thresher is not expressed, as inlet is open to threshing unit and top sieve surface. The approximate expression for the area can be expressed as

$$Ad = 2 \times (Lo + Wo) \times \Delta s \qquad (13.13)$$

Where,

Wo, width of outlet, m; Lo, length of outlet, m.

The outlet area is less as the air moving out is at higher velocity to throw the straw at a distance. Generally it is less than half of the inlet area.

Δs = annular space between the sieve and the threshing drum inlet in (m) and it is adjustable.

The inlet area is usually more than this due to perforation in the sieve, but it is not taken into account as the material is loaded on it during operation. For a 5 hp size thresher, the wheat grain output is around 220 –250 kg/h. When the thresher produces fine bruised straw, the non-grain to grain ratio may vary from 1.2:1. Assuming the extreme conditions with non-grain ratio of 1.25, the output of thresher would be 312 kg/h or 0.086 kg/sec.

The quantity of air required for cleaning the threshed material can be obtained by substitution of the value of qc taking λ equal to 0.14.

Therefore

$$Qa = qc/\lambda = 0.086/0.14 = 0.614 \text{ kg/sec} \qquad (13.14)$$

Therefore blower air capacity required for thresher of aspirating the bruised straw would be 0.614 kg/sec.

The velocity of air is obtained by considering the terminal velocity of straw particles and the density, V_t, ρ_p and ε. The density of straw is determined or assumed as 600 kg/ m^3, and ε = 10 and Vt = 4 the velocity of air is calculated using equation (13.12).

$$V_a = \frac{4}{\dfrac{1 - 6 \times (10)^3 \times 1.22 \times 0.14}{\pi \times 600}} \qquad (13.15)$$

$$= 9.3 \text{ m/sec}$$

This is the minimum air velocity to lift the straw at the inlet of blower.

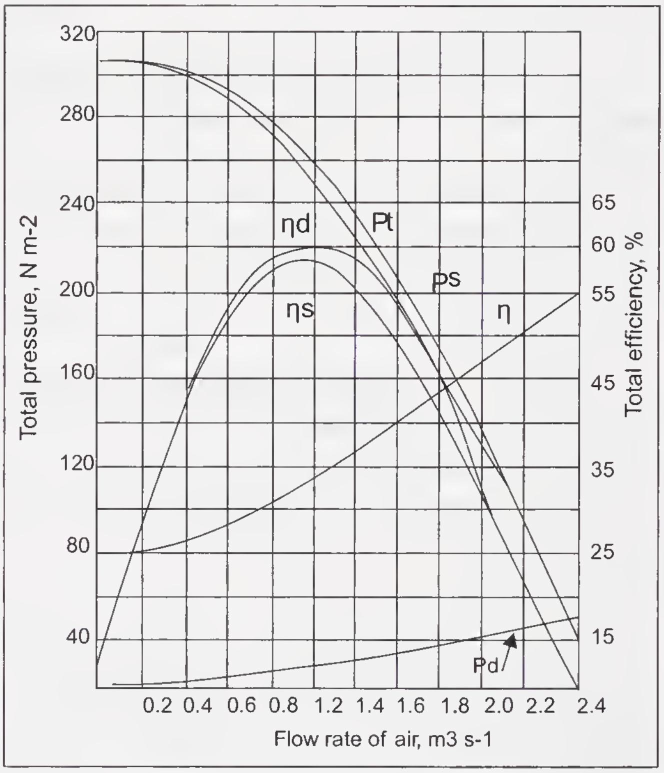


Fig. 13.7. Characteristic curves of blower.

The blower used on agricultural machines have efficiencies ranging from 30 to 68% depending upon the casing design and the number of blades.

Blower with radial set of blades in comparison to slanting blades, remaining parameters being the same, produce a higher velocity of air. On the other hand blower with slant blades produces a more compact air stream. The blades used on thresher have straight blades. Impellers with such blades provide large flow rates of air at low and medium pressures (Low pressure when air pressure H<1000 N/m^2 and high when H > 3000 N/m^2). The curved blades bent forward develop higher pressure than others, thus

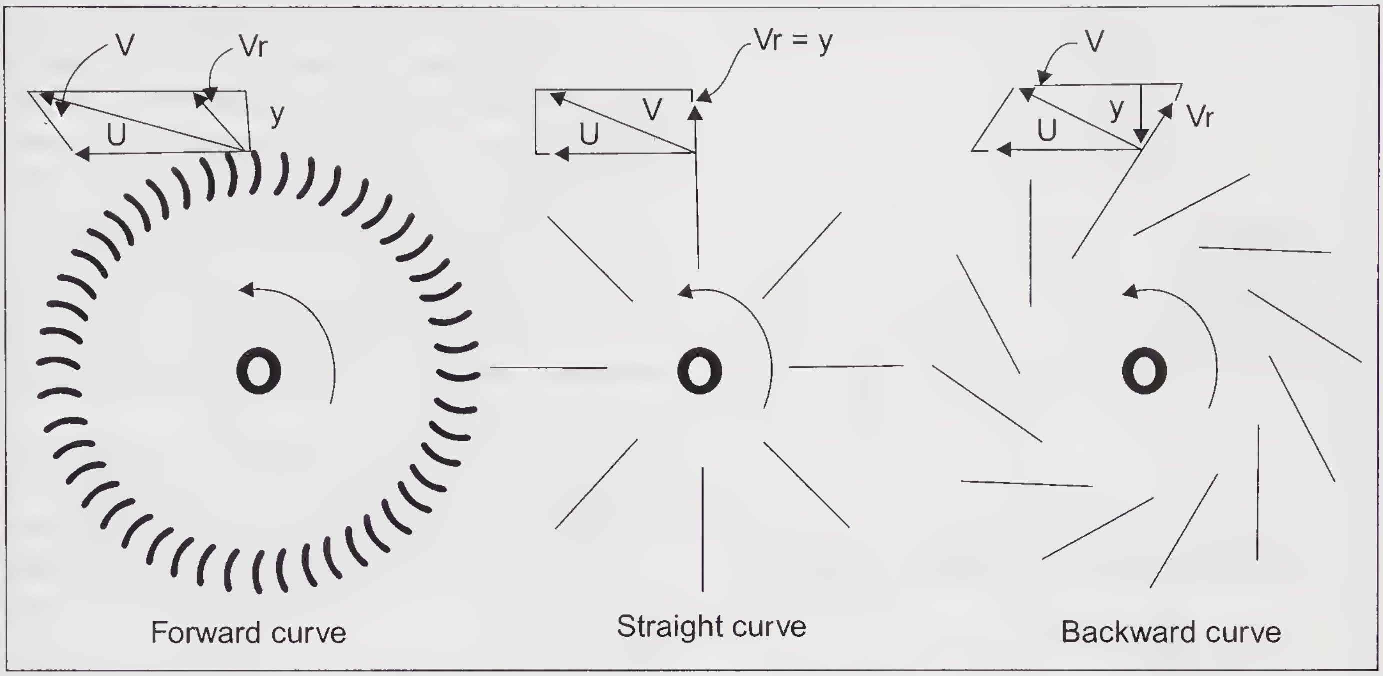


Fig. 13.8. The three types of blades used on blowers (forward, straight and backward curved type).

require high energy. Usually blowers have 4 –8 blades common on stationary threshers having concentric casing. The blower characteristics are graphically represented (Fig.13.7) and are indicated by number of curves. These are volume flow rate (Q_a) with total pressure head (P_t), including static head and dynamic head (P_d), with total efficiency (ηt) static and dynamic efficiencies (ηd) and power input.

Conveying forage with concentric casing has better performance when it sticks to the casing; of blower. For conveying dry materials as in the case of thresher blower with spiral casing have lower frictional losses, minimum recirculation of straw and high output (Fig. 13.8–13.10).

Design of blower, impeller and casing: The design of blower requires the information on the impeller inlet diameter, impeller outlet diameter, width of impeller, angle of blades and the type of blower casing required.

The blowers are centrifugal type with straight blades mounted on arms fixed at the blower shaft. The making of spiral casing is easy and is recommended and it would be easy to fabricate if a simple jig is prepared in

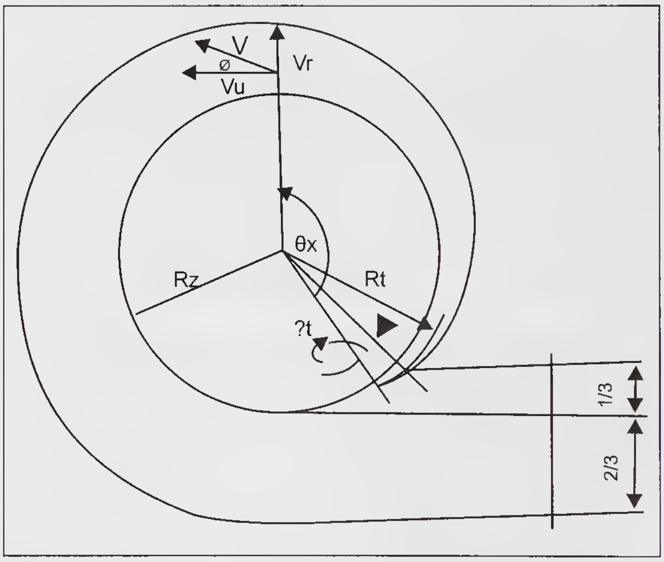


Fig. 13.9. Blower housing of involutes type casing.

the workshop.

The velocity of air at the inlet of impeller should be slightly greater than the value of $V_{a,}$ as calculated. The impeller area of inlet is reduced because the impeller is mounted on a shaft of diameter, which is normally 45 mm in diameter. Therefore D_{imp} = Di – shaft dia.

Thus D_{imp}= Di – 0.045

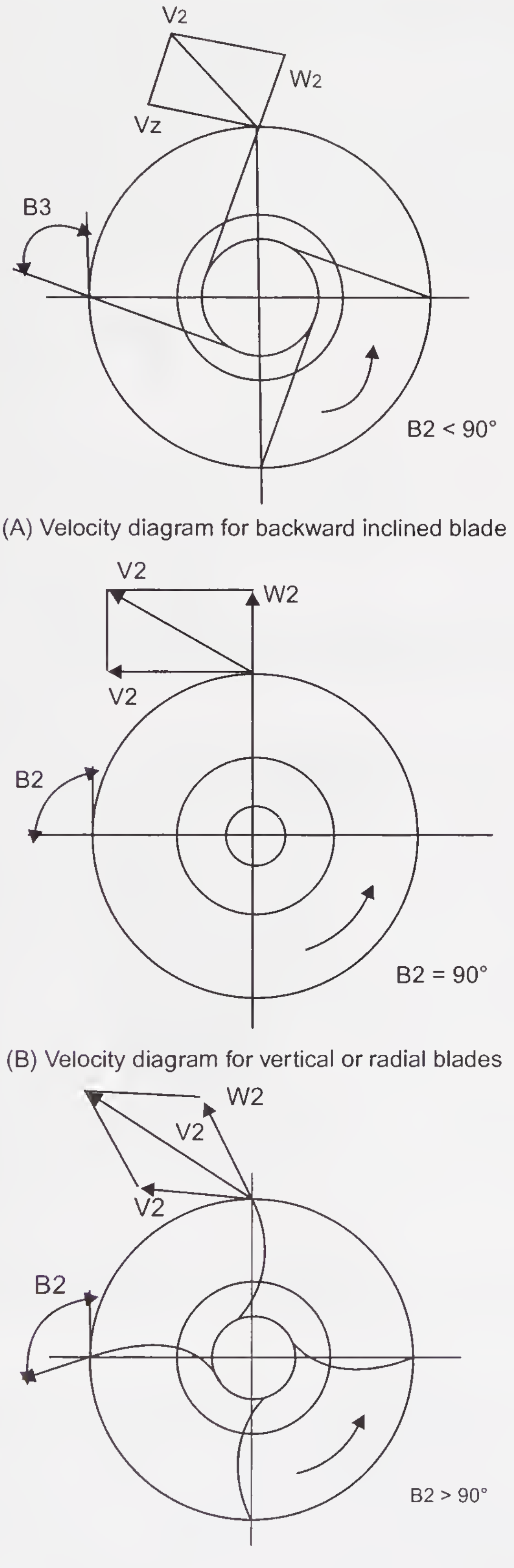


Fig. 13.10 (A-C). Velocity diagram at the blower blades for three types of blowers.

The value of Di is calculated using the simple relations. Normally blower casing has one inlet opening but in recent years the blowers have been developed with casing having suction openings on both sides. The one opening opens towards the threshing cylinder and the other to the grain outlet, which sucks light impurities when the grain is flowing from the top of sieve to grain outlet of thresher. The blower and cleaner arrangement is shown in the Fig.13.11.

The cleaning unit consists of two screens with reciprocating drive unit the suction inlet of blower opens on the top sieve of cleaner and the other suction tube extend on the lower sieve to suck up all the light chaff from separated grain.

The eye diameter for both sides of suction is

$$\mathrm{Di} = \sqrt{4/\pi \times 1/(2\times 9.0) + 0.045^2}$$

$$= 0.27 \text{ m}$$

The vane inlet diameter may be taken as equal to or slightly greater than Di.

The tangential velocity U of impeller

$$U = \frac{\pi \times D_i \times n}{60}$$

Where n is the rotational speed of the blower in rpm. Blowers are mounted on the threshing drum shaft and thus will have the same speed. If the blower is mounted on a separate shaft the speed could be selected between 800-1000 rpm. Substituting the value of n = 800 rpm,

$$U = \frac{\pi \times D_i \times 800}{60} \tag{13.16}$$

$$= 11.30 \text{ m/sec}$$

The inlet velocity V is assumed to be radial i.e. V1 =V2 and slightly higher than velocity of air V_a which was calculated as 9.0 m/sec. The value of V1 can be taken as 10.5 m/sec.

The tangent of inlet angle, at which the air enters the impeller of blower, is

$$\mathrm{Tan}\beta_1 = \frac{V1}{U1} \quad (13.17)$$

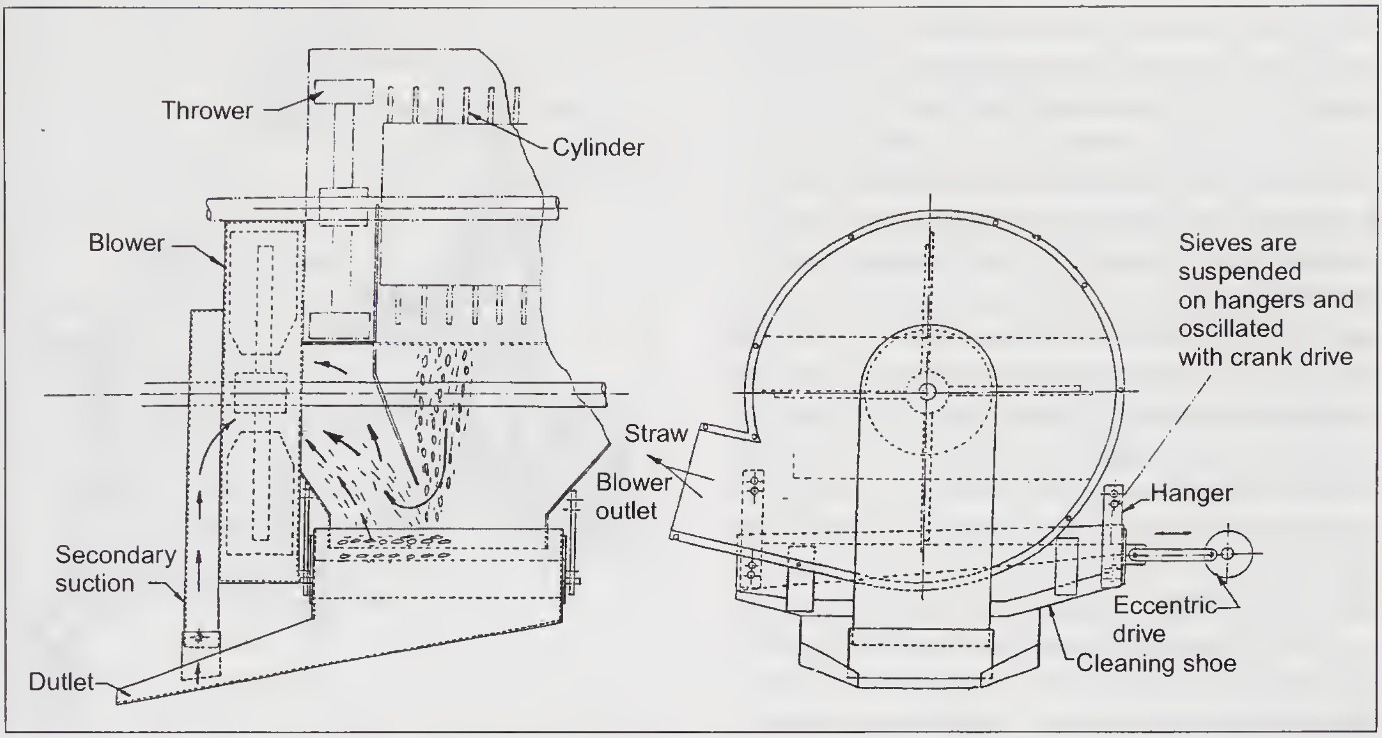


Fig. 13.11. Suspension arrangement used on cleaning unit sieves of CIAE thresher.

$= 10.5/11.30 = 0.92$

$\beta_1 = 43°$

Width of the impeller blades

The width of the impeller blades is computed from the following expression

$$Qt = \pi \times D_i \times b \times U1 \times e \tag{13.18}$$

Where Qt, theoretical air discharge incorporating efficiency; b, the width of the impeller blade, m; e, inlet concentration factor.

The inlet concentration factor is defined as

$$e = \frac{D_i - Z \times t/\sin\beta}{D_i} \tag{13.19}$$

Where Z, no of blades; T, thickness of blade, m; and β, impeller blade angle, and the value of β is 90° in case of radial vanes.

Assuming the blower efficiency of 50% and Qt = 2.0 m³/sec.

The value of blade width is calculated from equation (13.18).

$$b = \frac{2.0}{\Pi \times 0.027 \times 11.3 \times 0.99}$$

$= 0.210$ m .or 21 cm.

Outside diameter of the impeller: The outside diameter of the impeller is about twice that of the inside diameter. This should not be increased excessively as the power required is proportional to the fourth power of diameter. If required the dimension of the width of the blade and rotational speed of the blower be increased.

For throwing the straw at a longer distance the velocity of the air should be more than 20-22 m/sec. It has been established that the angle at which air with straw leaves the impeller should be the same as the diffuser angle of the spiral blower casing. For higher efficiency this angle is usually between 6°–10°. The blower speed is selected as 800 rpm.

Assuming exit air velocity V2 = 25 m/sec and diffuser angle as 8° for the radial blower,

$V2 = 25 \cos 8°$

$= 24.75$ m/sec

And the outside diameter of the impeller = $\dfrac{60 \times 24.75}{800}$

$= 0.59$ m (59 cm)

Thus from the above dimensions calculated blower impeller and casing be designed for the thresher to be designed.

The above example is given for the designers to grasp the principles of designs for the blower. The aim of designer should be to design the blower which should give the desired amount of air and velocity. It should not consume excess of power or energy. In case the speed is increased the power consumption would increase at a higher rate. Hence balance is to keep the energy consumption of blower to a level from 33 to 36% of total energy required during threshing in case of wheat threshers.

Blower for high capacity thresher

The blower designed above is for the wheat thresher where the grain output is limited to 240-250 kg/h or it would aspirate the mass of bruised straw of 300 kg/h. When designing high capacity thresher instead of increase the size of impeller etc, it was considered safe to keep the size of blower as 600 mm diameter with four blades but increase the number from one to three to remove the amount of *bhusa* produced during threshing of wheat and other crops. In high capacity thresher the cylinder width was increased to 110 cm. This helped in feeding the wheat crop in bunches and thus helped in reducing the manpower requirements in moving and feeding the crop into the thresher. Thus in this size of machine with three blowers were mounted on the single shaft to aspirate the *bhusa*. Thus this arrangement of cylinder and blowers worked well on the machine. The schematic diagram of the thresher is given in Fig.13.12. The unit was operated with tractor or 20 hp electric motor. The output capacity of thresher was above 1,300 kg/h for wheat, bengalgram and maize. It was 780 kg/h for soybean because of the cylinder operation was at speed of 8 m/sec. The threshing and cleaning efficiencies were above 99% and 98% respectively. Hence the thresher blowers can be designed on the above design principles.

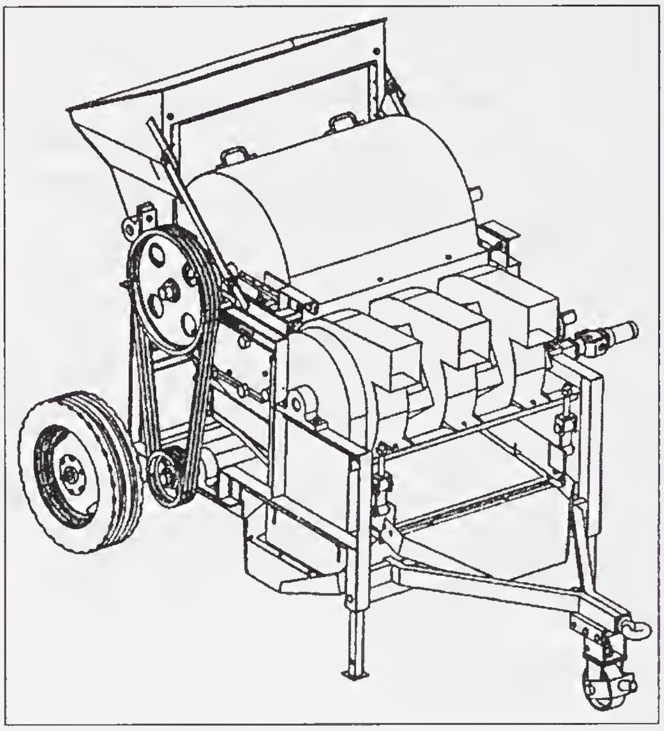


Fig. 13.12. High capacity thresher using three blowers for aspiratory cleaning.

Separation by winnower type blower

In aspiratory cleaning unit the air stream divides the threshed crop mass into two fractions, the light fractions that are lifted up and blown out. The wheat threshers have two air streams for cleaning. The primary suction inlet removes the light material such as *bhusa* or chaff. The second air stream removes the rest of the light impurities including light seeds. The value of air velocity for primary cleaning is high as it has to remove the non-grain mass of the threshed material. In case of secondary cleaning only a few per cent of light material as compared to grain is to be sucked out. The value of secondary suction be low to avoid the blower losses. The air velocity is changed according to the crop being threshed [Uhl and Lamp (1966)].

In winnower type-cleaning system the blower directs the air stream in inclined and horizontal direction. Here the mass of threshed material falling from the concave grate is subjected to air velocity and the dispersal of individual particles of grain and chaff or straw take different trajectories. Here the grain or

straw has initial velocity and enter the air stream or move along the sieve with inclined or horizontal stream blown over them.

The separation of grain from the mass occurs because the vertical component of velocity is small than the terminal velocity of the grain. The behaviour of particles and their motion depend on many factors. However if it is assumed that the air flow is uniform and the velocity of air V_a is constant. The forces acting on the particles are the gravity force and the force due to reaction acting in direction opposite to the relative velocity of particles.

The particle moves in the air stream along some trajectory under the action of force of gravity and the air stream. Let U'x and U'z are the components of velocity of air at point A in the x and z directions and v_x and v_z the velocity component of the air. The absolute velocity of the particles along the x and z directions are

$$U_x = v_x - U'x \quad (13.20)$$

$$U_z = U'z - v_z \quad (13.21)$$

Where U_x and U_z are the absolute velocity of particle along the trajectory.

The air stream if it is inclined at the angle γ, the value of v_x = Va cos γ and, $v_z = V_a \sin \gamma$

The inclination of absolute velocity of flow from vertical is given by angle

$$\alpha = \frac{U_x}{U_z} = \frac{V_a \cos\gamma - U'_x}{U'_z - V_a \sin\gamma} \quad (13.22)$$

As the particles moves the relative velocity varies both in magnitude and direction tending towards some limiting value and the critical velocity which is equal to critical velocity at this point the value of U'_x tends to be zero.

Considering the above conditions the value of

$$\tan \alpha_{cr} = \frac{Va \cos\gamma}{V_{cr} - Va \sin\gamma} \quad (13.23)$$

For the particles entering the air stream the critical velocity varies from the V_{cr} min to V_{cr} max and with increase in difference in the minimum and maximum values the divergence of the particles will be increased. Therefore the trajectories of the particles would be in the form of cluster. The divergence of the cluster depends upon the critical velocities and the direction of the air velocity. From the experiments conducted it is reported that reducing the angle of air stream reduces the divergence i.e. for horizontal flow of air the divergence is small because cos γ =1. The divergence is great for the value when cos γ <1. Further the divergence also depends upon the air stream velocity, it increases as the air velocity increases reaches maximum value but after that the divergence decreases (Fig 13.13).

The air velocity, which causes maximum dispersal of grain, is equal to the geometric mean of the two extreme values of the critical velocities. The value of angle γ of air stream coming out of the blower is in the range of 18–30°. The velocity of air blast is kept in the region from 5 to 6 m/sec for the dispersal of the mass of the threshed particles falling on the screen.

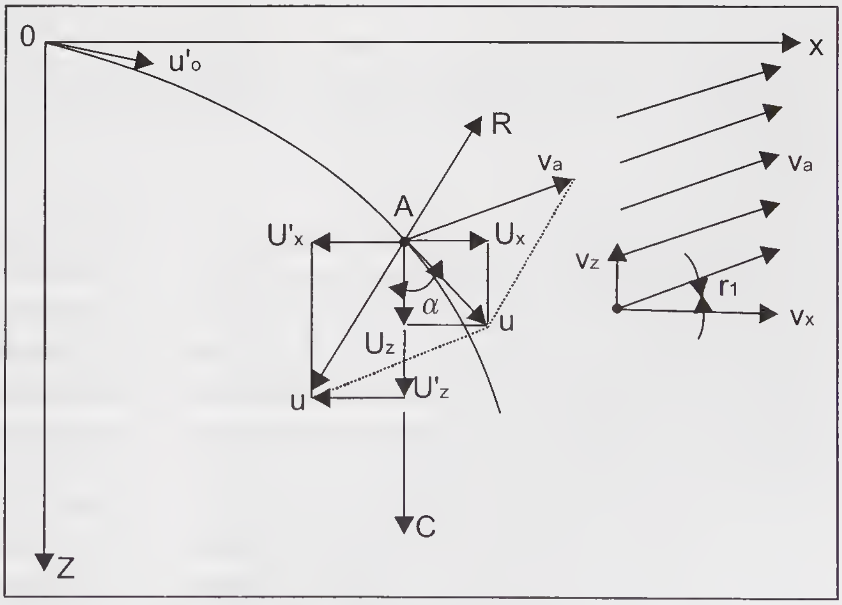


Fig. 13.13. Action of inclined air stream and gravity force on threshed mass of particles causing dispersal.

The size of air duct for the airflow towards screen is specified in terms of width of duct and the throat width of the cleaning sieves. The throat width is kept from 90 to 100 % of the width of the cleaning sieves. The throat width is kept as 100 to 120 mm. It affects the sieve capacity and the loss of grain. Throat width affects the spread of air stream along the sieve length and the velocity of air stream. The angle δ is the angle between the direction of airflow to the screen is selected as 25 to 30° for the best of air flowing over the grain mass. The expansion angle of air stream is assumed to lie in the range of 12 to 16° and the portion of sieve which is covered by the reflected flow or air is about 50 to 60% ($Ko\ S_d$). From these values the proper design of duct and its installation is achieved and the entire sieve length is covered (Fig.13.14).

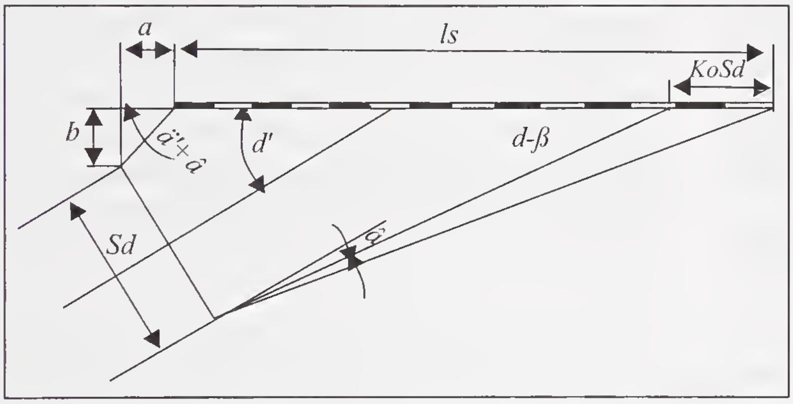


Fig. 13.14. Arrangement of the throat of the air duct for the cleaning shoe.

Selection of blower

The principle data for the selection of blower are the velocity of air at the exit duct, the quantity of air required for the desired flow rate and the total pressure of air that must be developed by the blower. The total pressure is the sum of pressure loss due to system used and the velocity head required for moving the air stream. The terms blower and fan are often used interchangeably. A fan normally refers to device which deliever large volume of air at low pressure (0.07 kg/cm^2). However the blower is designed for blowing air at high pressure. In cleaners and winnowers used for removing chaff, etc. from grain centrifugal blowers are used. In most of threshers marketed it is the centrifugal type fans, which are used with radial blades. The number of blades is usually 4; for increasing the volume of air to blow over sieves the width of fan is increased to the width of sieves. The diameter is normally kept according to space available on machine. The small diameter is preferred to reduce power input.

Screen separation

A large portion of straw, broken grain, lighter seeds, grains and dust particles are sucked and blown out through the aspirator blower before it strikes the top sieve surface of the cleaner. The concave grating on stationary thresher allows only a small size bruised straw with grain on the screen. In axial flow thresher however the cylinder moves a sizeable quantity of straw to thrower from where it is thrown out. Small size particles of chaff and straw pass through the top grate and fall on the sieve surface from where it is blown out. The separation of the grains from the mixture of grains and fine non-grain material or straw is achieved by a vibrating inclined sieve. It depends upon the aerodynamic and mechanical separation. For the aerodynamic separation it is essential that the particles lose their contact with the sieve intermittently during vibration. During vibration the smaller size particles have tendency to penetrate between components of larger dimensions. As a result, small size particles reach sieve surface and pass through its openings and continue during the entire period of displacement of layer or mixture along the sieve surface. Major parameters in design of screen separators are given below.

Types of screen: Size and type of perforation; Surface area of the sieve depending upon the loading per unit sieve area; Length

of sieve; Vibration of sieves or screens; Strokes per minute; Length of stroke; Inclination of sieve; and Type of motion of sieve.

Sieve selection: Three dimensions govern the geometric size of particles: thickness, length and width. The largest dimension of a particle is length, smallest is thickness and in between dimension is its width. These physical dimensions are utilized in screen separation The various types of sieves that are used on threshers for separating grains from the straw and chaff are: Round hole sieves; Elongated hole sieve or slotted sieve; Triangular hole sieves; and Griepel or pocket sieves. The various types of sieves are shown in Fig.13.15.

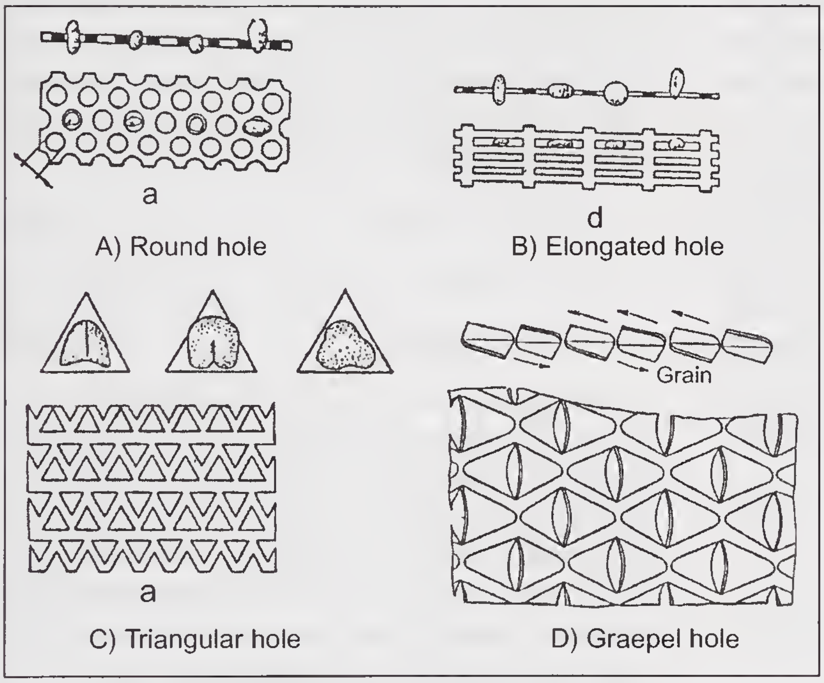


Fig. 13.15. Various types of sieves used on threshers.

Round hole sieve: In the round hole sieve material is graded according to width i.e. particles whose width is less than the diameter of the holes on the screen surface. Effective grading according to width through hole occurs when the particles or grains lie along the axis, normal to the surface of the sieve. For this the sieve must vibrate vertically. When the length of grain is no more than the twice the width, the grading is satisfactory even on sieves which vibrate horizontally. The top sieve in most of the threshers for separating grains like wheat, soybean, paddy, sorghum, bengalgram, greengram, pigeonpea, maize, etc a round hole sieve is used. However for paddy or rice slotted sieve is recommended.

Slotted or elongated hole sieve: In this sieve material is grade as per the thickness of the material. The material to be screened must swing edge wise and lie along the length of slot. This condition is satisfied with horizontal vibrations of the screens. The material should be moved without being tossed up so that the grains turn around its larger axis. In these screens if the material is tossed up from the screen the output of machine is reduced.

Triangular hole sieve: Triangular hole sieves are used to separate grains, which have triangular shape. Such sieves are usually used in cleaner and graders for removing weed seeds.

Griepel or pocket sieve: In case of material where large difference occur in the size of grain and straw coming out of threshing unit special sieve called griepel or pocket sieves are used. This type of sieve is mostly used in combine harvesters as top sieve of cleaning shoe. This sieve helps the long size straw to move out of machine and allows the grain to fall on the second sieve.

The size of the hole of the sieve for a particular grain separation is selected according to their gradation. There may be separation from straw or separation of various fractions of different thickness, length or diameter. Depending upon the grains the sieve hole size 'h' may be approximated from the expression given below:

$$Af >= Mav - (1.5 \text{ to } 2.0)\, \sigma \quad \text{for fine sieve} \tag{13.24}$$

$$Ag = Mav - \sigma \tag{13.25}$$

for grading sieve which deliver second quality material.

$$Ac = Mav + 3\sigma \quad \text{for cereal crops} \qquad (13.26)$$

Where,

Mav = average fraction of material by weight in a particular size gradation.

σ = root mean square deviation for the size dimension considered for sieving.

From the theory of probability the normal distribution of size characteristics (99.7%) of the entire produce is covered within the limits of Mav ± 3σ where σ is the standard deviation of the size of grains or particles.

Sieve loading

The movement of grains through the sieve openings depends not only on their shape and vibrations of the sieve but also on the loading of the sieve i.e. the thickness of material on the top of sieve. The quantity of grain mix delivered to the top of sieve affects both the cleaning efficiency and the total output. With increased loading, the cleaning efficiency falls but the total output is increased. Experiments have shown that the output of the sieve is proportional to the area of the sieve. Let As be the area of the sieve, and qs be the output of sieve then,

$$qs = q \times As \qquad (13.27)$$

Where,

q is the specific loading per unit area of sieve in kg/m^2

Table 13.4 shows the specific loading rates used in combine harvesters and seed cleaners and for rough cleaning of the threshed material viz. preliminary cleaning. The specific loading for wheat grains is in the range of 1.5-to 2.5 kg/ m^2.

The separation of grain from straw on the sieve not only depends upon the thickness of layer but also on the length of the sieve, sieve width and the proper selection of hole size. In thresher designed in India the length of the sieve is slightly less than the thresher drum length and width also less than the width as the drum is mounted on the angle iron frame. Knowing the expected grain output the length of the sieve is calculated.

Table 13.4. Loading rates used for cleaning of grains in different types of machines

Type of cleaning unit	Specific loading rate
Combine–cleaning shoe sieve	1.5-2.5
Preliminary cleaner-scalper	1.6-2.0
Seed cleaner or grader	0.5-.60

Vibration of screens

The sieves in stationary thresher usually have four bar linkage mechanism (parallelogram type). The motions of the oscillating sieve for the small value of crank /connecting rod ratio (r/l) are given by the following equations:

$$X = r\,(1-\cos \omega t) \qquad (13.28)$$

$$X' = \omega r \sin \omega t \qquad (13.29)$$

$$X'' = \omega^2.r.\cos \omega t \qquad (13.30)$$

The important point for designing the sieve is the selection of frequency and amplitude means stroke length as these affect to a decisive extent the operational quality of the sieves. In most cases the crank length is adjustable and thus stroke length can be changed easily. The speed is mostly fixed on the threshers. The sieves are vibrated in longitudinal direction.

The inclination angle of the sieve surface of the upper sieve varies from 4-9 degrees and of the lower sieve 0-5 degrees. During vibration the sieve imparts velocities to the particles on the surface in vertical and horizontal direction. When the acceleration in vertical direction is greater than the weight of particle it lifts and moves axially a short distance. The force in horizontal direction should be less than to overcome the friction so that the particle moves horizontally during its floatation. The greater forces would move particles with

speed over sieve surface with the effect there would be less of cleaning or separation of particles. The sieves are provided hangers so that the inclination can be changed in case the movement of material is a problem. In most of the stationary threshers the sieves are not provided with cleaning brushes to keep the holes open during operation hence when there is lot of trash in the threshed mass the operator should see that the flow of material is proper and no accumulation of mass should take place on the sieve surface. This increases the sieve overflow losses.

The cleaning systems used on threshers are of two types i) in this system the threshed crop along with straw falls on the top sieve of cleaning shoe where entire mass of crop material is aspirated to get the clean grain. ii) In other system the most of straw or plant material is ejected out of threshing unit and only a small portion of chaff and straw falls with grain on the top sieve. Here the cleaning is done by a winnower type fan or blower. In both the methods of cleaning mechanical separation and air separation methods are used to achieve the cleaning efficiencies of 98% or more. In some crops where grain per cent is very less, it is recommended to further clean the crop with the seed cleaner before keeping the grain in storage structure.

❑

14 Thresher for Experimental Studies

Single ear thresher 210

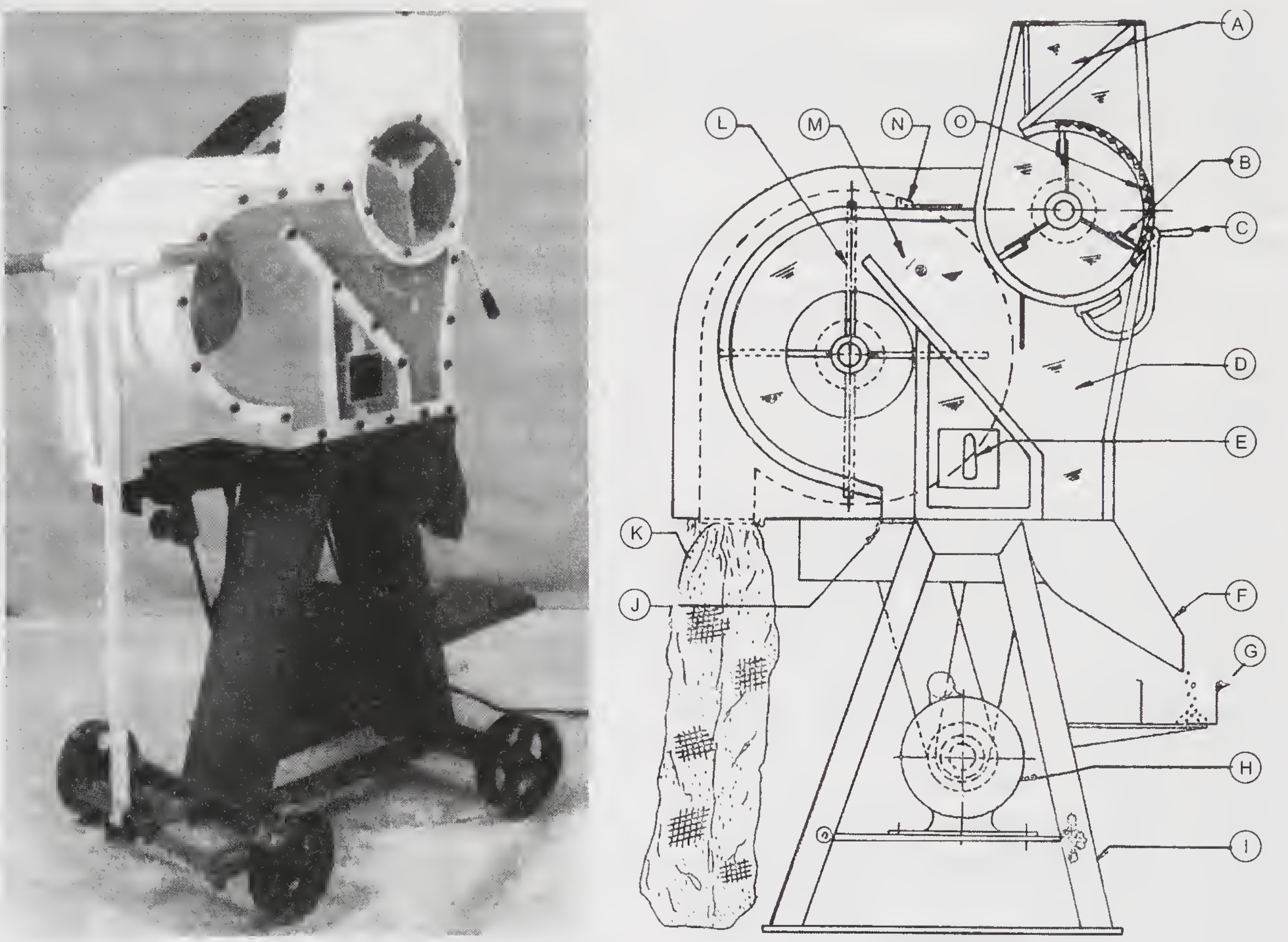
Plot thresher for field experiments (Fig. 14.2 A-B) 214

The development of new varieties to suit the local agro-climatic conditions requires screening of a large number of varieties to select a few for breeding new varieties having the desired traits. Hence machine for threshing of individual plant is required. The main aim is to have thresher, which should thresh and clean seeds of the selected plants with minimum of damage. The machine should be clean completely of any seed or grain remaining inside while removing the sample threshed. Here the main criterion is to recover 100% of the threshed grain. In the past this job was performed manually by laboratory worker/helper. But with modernization in the logging of data of the field experiments, the need for such machines has become a reality at most of the research stations. The two most important threshers are the single ear thresher for threshing of ear/or bunch of ears or pinnacles of crop like wheat, paddy crops.

The second machine required is the plot thresher for threshing the crop samples harvested from the field plots. As the plot size may vary with type of experiments planned the sample size can be up to 10 –15 kg only. Thus the samples are to be threshed by the thresher completely without damage to seed. It should also clean the threshed grain for use as seed. Here emphasis is to thresh and clean the samples without mixing of seeds of one sample with those of other. These two machines were developed and evaluated during 1986-1990 at CIAE, Bhopal and later on popularized among the plant breeders in India.

Single ear thresher

The single ear thresher developed at CIAE, Bhopal was developed after reviewing various designs use by scientists and considering the principle of cleaning seeds by aspiration. It consisted of a feed inlet, threshing unit, aspiration column, light seed gathering chamber, blower and blower outlet with chaff collecting bag (Fig.14.1a,b). To make operation visible to the operator one side of machine is covered with a clear Perspex sheet. The threshing time can be controlled till the grain is separated form the ears. The ears of wheat or other crops are fed through the feed inlet. The beating and rubbing action caused by the beaters help separation of grain from ears and break the straw. The rough is created in the



(a) (b)

Fig. 14.1 (a-b). (a) Single ear thresher developed at CIAE, Bhopal. (b) Schematic diagram of single ear thresher A, Inlet; B, cylinder beater; C, lever; D, aspiration column; E, electric switch; F, Feed outlet; G, tray for grain; H, electric motor; I, frame; J, outlet at blower inlet chamber; K, trash bag; L, blower; M, air passage; N, air control gate; O, concave.

threshing cylinder for the portion covered with mild steel rods of 6 mm diameter and the gap between bars is filled with inclined strips so that the grain is not lodged inside the chamber. The lower portion of chamber is hinged and kept closed by spring action to allow the threshed crop drop into the aspiratory column. The blower creates the air draft so that the light material is sucked up the air passage into the air chamber where the grain is thrown towards the outer wall of the chamber and the light material along with the air is sucked by the blower and thrown out from the blower outlet into the nylon bag made of mosquito net to collect the chaff and the broken or shriveled seeds. The net allows the air to escape. A sliding gate provided on the inlet chamber of blower controls the blower suction. Changing the pulley of motor or the pulley on blower changes the speed of blower.

Specification of the machine

Type	To thresh single ear or bunch of ears in batches
Dimensions	length 735 mm, width 425 mm, height 1,176 mm
Weight	74 kg
Suitable for crops	Wheat, chickpea (*cicer arietinum* Linn.) lentil (*lens culinaris* Medikus)

Diameter and no of beaters	210 mm, 3 adjustable for clearance
Concave	Closed type with rubbing bars
Cleaning system	aspiratory type
Diameter of blower	350 mm with 4 blades
Motor	0.5 hp single phase, 220 volt, 50 cps 1425 rpm
Motor pulley	Step cone type with pulleys diameter of 50, 65, 82 and 100mm
Cylinder pulley	150-mm or more according to crop
Estimated cost	₹ 6,000 (1987)

Tests on wheat crop: The machine was evaluated for threshing of the samples of wheat, chickpea and lentil crop (Table 14.1 and 14.2). For threshing wheat the cylinder beater speed was 710 rpm or 7.81 mps. The clearance was set at 2.5 mm. This clearance was set close to wheat seed size to avoid seed damage during threshing of samples. The speed was also set at low level to prevent the seed damage. The blower speed was set at 1,868 rpm at this the suction of blower was to suck out the chaff and grain was not sucked out as noted in preliminary trials.

The performance of thresher on wheat indicated that the threshing efficiency was 100% for most of the wheat samples. The cleaning efficiency was 98.58% to 100%. The grain loss due to blower was less than 0.5%. The seeds blown out were mostly light and undersize grains. The visible damage was 0.4%. The machine was able to recover 99.4% of grain as compared to manual method. The seed germination was 97.25%. The performance on wheat was high.

Tests on chickpea: The whole plant sample threshing of chickpea sample of 'C 235' showed threshing efficiency of 99.67%. The cleaning efficiency was 95.06%. This was due to fall of thin long stems with the seed at the main grain outlet. The increased air suction resulted in more of blower loss. It was easy to remove the long stems from the clean seed to clean the sample. The average seed damage was 0.31%. The germination was 97.5%.

Trials on lentil: The stems of 'JLS 1' lentil were thin and did not break into fine pieces hence machine was set to avoid seed loss. The threshing efficiency was 99.47%, cleaning efficiency was 99.84%. The seed germination

Table 14.1. Threshing of wheat samples with single ear thresher and its performance.

Sample weight (g)	Clean grain (g)	Un-threshed grain (g)	Grain at blower inlet (g)	Grain at blower outlet (g)	Chaff in clean grain (g)	Broken grain (g)	Total grain (g)	Threshing efficiency %	Cleaning efficiency %	Blown grain %
10.5	6.80	0.09	0.0	0	0.01	0	6.89	98.70	99.85	0.0
10.0	6.35	0	0.03	0	0.09	0.03	6.38	100.0	98.58	0.47
10.0	6.50	0.03	0.0	0	0	0.03	6.03	99.60	100.0	0
11.0	7.95	0	0.06	0	0.01	0	8.07	100.0	99.87	0.75
10.5	6.65	0	0.03	0	0.05	0	6.68	100.0	99.25	0.45
10.3	6.70	0	0.09	0	0	0	6.79	100.0	100.0	1.32
10.5	6.80	0	0.0	0	0	0	6.8	100.0	100.0	0
10.6	6.95	0.0	0.0	0.01	0	0	6.95	100.0	99.85	0
11.0	7.10	0.03	0.0	0	0.01	0	7.13	99.60	99.86	0
10.5	7.00	0.0	0.03	0	0.03	0.03	7.09	100.0	99.57	0.43
10.0	6.70	0.09	0.0	0	0	0.03	6.79	98.70	100.0	0
			Mean					99.69	99.79	0.31

Table 14.2. Performance values of single ear thresher on three crops

Description	Crop		
	Wheat	Chickpea	Lentil
Crop parameter			
Variety	Sujata	C235	JLS1
Moisture content of grain % (db)	6.20	-	6.9
Grain % in crop	65.98	50.12	49.3
Machine setting			
Beater speed (rpm)	600	530	530
Linear speed mps.	6.25	5.52	5.52
Blower speed	1,860	1,860	1,860
Motor speed	1,425	1,425	1,425
Concave clearance	4.0	4.0	4.0
Performance			
Mean threshing efficiency %	99.94	99.67	99.47
Mean cleaning efficiency	99.97	95.06	99.84
Mean visible seed damage %	0.31	0.31	0.98
Average germination %	97.25	97.5	100
Grain at blower inlet %	0.25	0	1.12
Grain at blower outlet %	0	0	0.31

was 100%. Only 1.12% of light seed were collected at the blower inlet.

Threshing of other crops: For paddy the panicle can be separated from the straw and threshed in the single ear thresher. In other case only the panicle head is fed into cylinder and is stripped of the straw by the cylinder beaters.

The sorghum ear head can be individually threshed in the single ear thresher. The time of operation can be increased till all the seeds are separated before released in the air stream. Similarly pearl millet ear head can be threshed individually. In pulses like green gram, black gram etc; the pods can be threshed in this thresher. In other crops like maize the tubular maize sheller can be used to shell the kernels of single cob. In sunflower, by using the small scraping bench can scrape the single flower head seeds. For groundnut crop the pods from the single plant can be stripped using the stripping comb type device. These devices are shown in respective chapters/paragraphs.

Plot Thresher for Field Experiments (Fig. 14.2 A-B)

It is a small size thresher for threshing of samples of different crops from the experimental plots to determine the crop yield values. As the size of plots for field experiments may be 5 to 10 square meters in size the commercial threshers are very big for completing the job. The manual method of threshing would involve extra labour and time, therefore, there are chances of mixing of samples and loss of grain due to delay in threshing of samples. Thus plot thresher was designed so that the field observation of crop samples can be analyzed speedily and without mixing of samples and loss of grain during the operations. It would also require less amount of labour in performing field experiments. The other requirement is that the grain of one sample should not be left in the machine to contaminate other samples. Hence all the parts of thresher be reachable and cleaned.

Description of thresher: The plot thresher

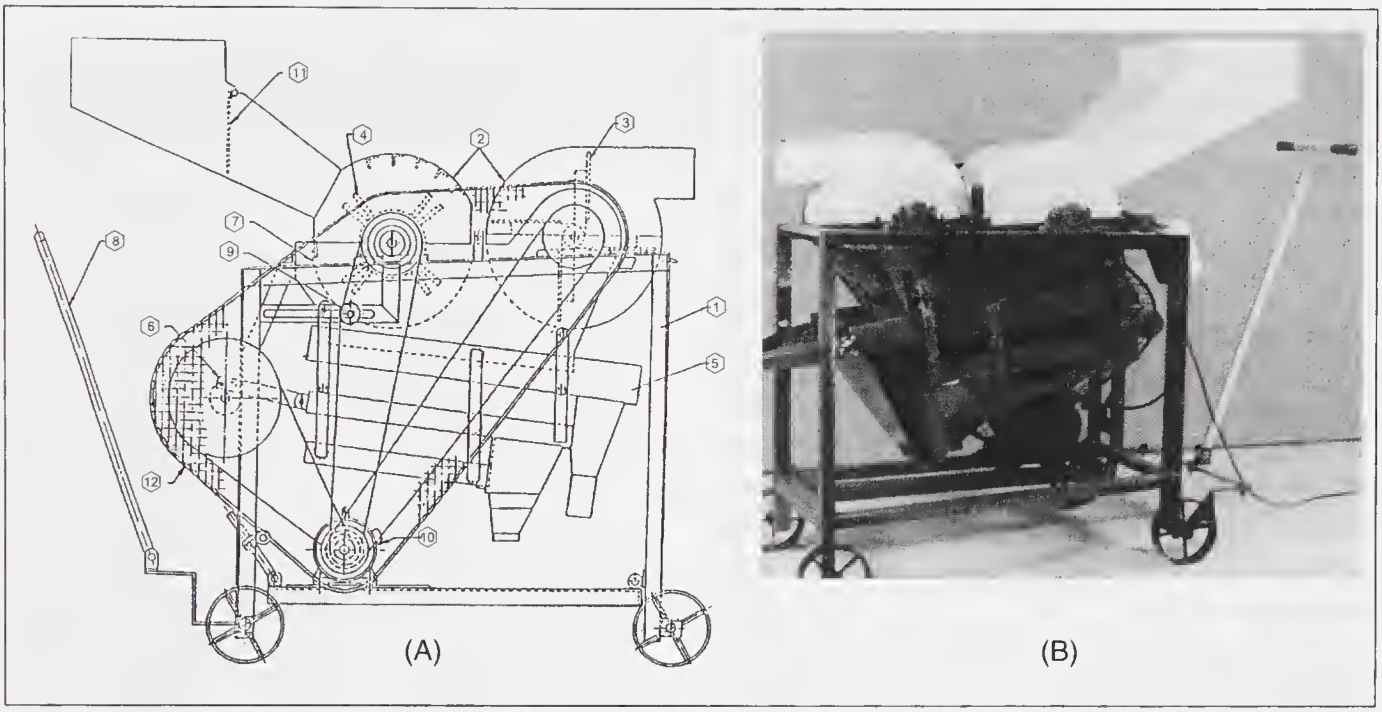


Fig.14.2 (A-B). CIAE multicrop plot thresher. 1, Frame; 2, Body; 3, Blower fan; 4, Cylinder; 5, Sieve; 6, Eccentric; 7, Concave; 8, Handle; 9, Idler pulley; 10, Motor; 11, Hinged plate; 12, Belt guard.

consists of spike tooth type threshing cylinder of 250 mm in diameter fitted with 10 mm diameter spikes bolted on cylinder in four rows in staggered fashion. The concave grate is made of 6 mm square bar with 7 and 9 mm gap in between rods for threshing of number of crops. The concave grate is made by welding the square rods on the two semicircular discs or plates with spacing of 7 and 9 mm in between the bars. The cylinder top cover is made of circular type from mild steel sheet and angle iron pieces of 25 × 25 × 3 mm size are welded on the inside of cover parallel to cylinder axis to act as the rubbing bar for threshing of crop.

Feeding hopper: The crop-feeding hopper is welded to the top cover of the threshing cylinder, which is hinged to the main frame of the machine. The hopper can be lifted up for visual observations and clearing of concave and cylinder. A hinged plate in the feed hopper stops the back flow of grain through the hopper during threshing.

Cleaning shoe: The cleaning unit consists of three-sieve assembly with separate outlets for separating heavy pieces of straw from the grain by top sieve. The grain passes through the top sieve and falls on the middle sieve which separates the fine material such as dust, shrivel seeds and weed seeds. The clean grain flow out from the middle sieve outlet. The fine material is collected at the bottom outlet. The assembly unit is oscillated by eccentric drive having provision for change of amplitude of oscillations.

Blower: An aspiratory blower is provided on the separate shaft behind the threshing cylinder. The straw and chaff from the top sieve are sucked by the blower and blown away to one side of machine. The blown material can be collected if required by attaching the bag at the outlet.

Drive system: The thresher is powered by a 0.75 kW single-phase electric motor, mounted on hinged base plate. A 4- step V grooved pulley is fitted on the motor shaft. The small size of pulley is 50mm, and used to drive the sieve shaker assembly through a v

belt drive fitted with 225 mm diameter pulley. The second step pulley of 65 mm diameter drives the threshing drum. The step pulley on threshing drum shaft can give different cylinder speeds for different crops. The third pulley of 82 mm diameter on motor is used for driving the blower shaft fitted with 125 mm diameter pulley. The motor is mounted on the hinged platform and slotted channel for proper positioning and alignment. The idler are provided for tightening of belts for proper operation of the thresher.

Working principle: The crop thresher is useful for threshing of crops like wheat, gram, sorghum, soybean, safflower, etc. For crops like wheat, safflower and pigeon pea, the flowers, ear heads or pods are in the top portion of plants and therefore only the top portion is fed into the threshing drum as in threshers with hold on system of feeding the crop. In crops like gram and soybean, the whole plant is fed into the machine but gradually to avoid choking of the cylinder or not to cause overloading. The separation or threshing of grain is done at the threshing unit and the grain and straw passes through the concave grate and fall on the top sieve of the cleaning unit. The straw and light material is sucked out by the blower and the seeds are separated through the sieve. The heavy straw or nodes pass over the top sieve and are collected separately. The fine chaff and dust passing through the second sieve is collected at the dust outlet. Before threshing the crop proper sieve and concave are to be fitted and speed are set as recommended for the crops for proper functioning of the machine.

Specifications of plot thresher

Type	Spike tooth type cylinder
Dimensions	1320 x 820 x 1285 mm.
Weight	120 kg
Suitable for crops	Wheat, gram, sorghum, safflower, soybean, pigeon pea, pearl millet etc.
Power unit	0.75 kW, 220 V single-phase motor of 1,440 rpm.
Drives	V belt and pulleys and provided with idler pulley for tightening the belts of 4.0 cm diameter flat type
Belts	A size of 67, 56 and 47 for motor to blower, shaker and shaker drives
Type of crop feeder	Manual chute type
Height	1,285 mm
Opening size	260 × 100 mm
Threshing cylinder diameter and length	250 × 250 mm
No of spikes	36 in eight rows
Size	10 mm diameter and 75 mm long
Concave	Grate type made from 6 mm square bars with 7 and 9 mm gaps. It can be made according to size of grain to be threshed.
Width and length of blower	250 mm and 480 mm
Size	290 mm diameter aspiratory type inlet 140 mm diameter on two sides
Outlet size	130 × 100 mm.
Shake type	Oscillating type
No. of Sieves	Three, Top sieve 9 or 6 mm, centre 2 mm and bottom sieve is plain sheet.

The performance of thresher on different crops as shown in Table: 14.3 indicated that it can thresh the crops samples from 6 kg to 35 kg/h in safflower and sorghum ear heads. The broken grains in most of the crops were very low only for few crops it was around 0.75%. The blower losses were also less than 0.3%. The grain recovery in all crops threshed were above 99.69%.

Adjustments provided on plot thresher: The following adjustments are provided on the plot thresher to take care of different crops (Table 14.4)

Cylinder speed: The cylinder speed can be varied from higher of 1,250 to lower 750 rpm. The variation is achieved by changing the size of pulley on the cylinder shaft. In wheat and sorghum, the speed setting is 1,250 rpm and in other crops such as gram, soybean, safflower, pigeon pea, pearl millet etc. it is 750 rpm. Low speeds are used for threshing easy to thresh crops and for threshing crops like wheat etc.

high speed are used. Here the purpose is to thresh the crop without grain damage and not to aim for high output as the size of samples is small.

Concave clearance: It is made with fixed clearance but if the clearance is to be increased, it is to be adjusted by reducing the length of pegs fixed on the drum. The cylinder pegs are bolted on the cylinder. The concave of different sizes are provided with gap between bars as 7mm, 9mm and 12 mm. Thus most of the crops are taken care by the three concaves.

The blower speed is not changed as it is set for aspirating the threshed material falling on the top of cleaning sieve. In case the straw material is not broken by the cylinder it would

Table 14.3 Performance of Plot thresher on threshing of samples of different crops

Particulars	Crop and variety						
	Wheat (Sujata)	Gram (G-62)	Sorghum (CSH-9	Soybean (JS-7244	Safflower (JSF-1)	Pigeon pea (JA-3)	Pearl millet Local
Feeding method	Hold on	Complete plants	Only ear heads	Complete plants	Hold on	Hold on	ear heads
Grain straw ratio	0.79	1.09	3.01	0.562	0.244	0.265	0.666
Grain M.C. %	7.6	7.2	7.8	8.8	5.8	10.53	6.02
Straw M.C. %	6.5	7.5	9.3	9.4	7.3	8.56	9.15
Cylinder speed rpm	905	680	1,260	680	745	745	795
Blower speed	935	920	920	930	932	910	915
Shaker speed	302	290	290	285	288	285	282
Av. wt. of sample (kg)	3.6	1.25	5.14	11.34	1.58	4.0	3.29
Threshing time (min)	3.2	2.5	6.64	7.13	2.69	2.49	2.79
Output (kg/h)	29.5	15.93	35.15	34.2	6.46	20.76	55.61
Threshing efficiency %	99.11	98.04	99.04	99.38	100.0	98.90	96.89
Cleaning efficiency %	96.95	87.8	97.52	88.0	93.28	89.73	97.27
Broken grain %	0.0	0.78	0.16	0.75	0.0	0.24	0.09
Grain recovery %	99.83	99.75	99.84	99.83	99.69	99.84	99.81
Blown grain %	0.175	0.25	0.17	0.17	0.30	0.16	0.19

Table 14.4. Recommended thresher setting for different crops·

Crop	Concave clearance	Concave opening mm	Cylinder speed	Pulley size on cylinder	Top sieve size mm
Wheat	15	7	1,250	75	6.0
Gram	20	7 / 9	750	125	9.0
Soybean	20	7 / 9	750	125	9.0
Safflower	20	9	750	125	9.0
Sorghum	15	7	1,250	75	6.0
Pigeon pea	15	7	750	125	9.0
Pearl millet	15	6	750	125	6.0

fall as big pieces and it is discharged from the top of the first sieve of shaker assembly.

Shaker assembly: The adjustments provided are for the change of the size of sieves to suit the crop being threshed, changing of the stroke length and also the slope of the sieves as required.

By using the plot thresher most of the crop samples can be threshed with the machine. The main consideration should be to try to reduce the moisture level so that the plant material becomes brittle. As the output is not the criterion the crop retention time in the threshing cylinder can be increased.

Thus the threshers described above can take care of the threshing of crop samples handled by the plant breeders performing field experiments. In case of large scale field experiments the plot combines are utilized to harvest and thresh the crop samples. A large number of these machines have been supplied to plant breeders of various research Institutes of ICAR and to various State Agricultural Universities in India by CIAE, Bhopal under the World Bank programme of mechanization of field experiments. These machines are also useful for testing of threshers to determine straw grain percentages.

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15 Power Transmission System

V. Belt drives on thresher 218
Motor mountings 220

The power threshers are mostly manufactured for an operation with an electric motor and also an engine. In many areas the electric power is available and it being low cost therefore operation with electric motor is preferred by the farmers. These threshers are mostly of 5 hp or 7.5 hp size ranges because of the small farm holdings. The motors used on thresher are of three-phase induction type and have speed of 1,440 rpm. When thresher is operated with petrol engine the speed of engine is around 3,000 rpm. The cost of petrol being high, such prime movers are not preferred to power the machine. When operated with diesel engine the speed is around 1,500-1,800 rpm. Thus depending upon the use of power source the drive system is to be designed to operate the thresher units at proper operating speeds according to the crop being threshed.

V. belt drives on thresher

In stationary threshers the power from motor or prime mover is transmitted to three major components. These are threshing unit, cleaning sieves and the blower. In large capacity threshers the power is also supplied to grain auger or grain lifter. The threshing cylinder speeds are recommended for the different crops. These are based upon the experimental data. The speeds for threshing cylinder can vary from 5 mps to 20 mps or more to take care of different crops. Similarly speed of blower is also kept constant for a particular crop to keep the blower losses at low levels. The variation in airflow rate is achieved by controlling the gate or the inlet opening. However the different crops and grains have different terminal velocity and therefore the blower speed is set according to the recommendation of the manufacturers for the particular crop (Table 15.1).

In blower where it is used to aspirate the bruised straw from the cleaning shoe the quantity of material other than grain to be handled is more, and it would require more amount of air to lift and throw it. The cleaning sieves are mostly operated at constant crank speed. The stroke length is varied based upon the crop to be handled. In some crops the slope of sieves is changed to achieve smooth flow of grain and proper cleaning. The details of drive arrangements for the threshers are shown in diagrams Fig.15.1 and 15.2. The V belt drives are widely used by the industry as all types and

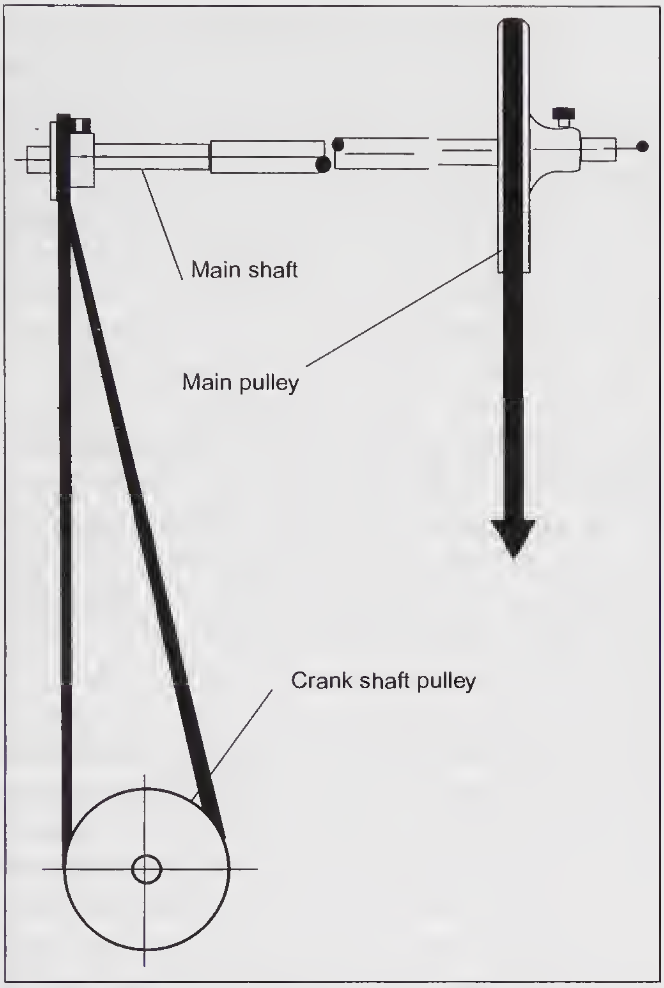

Fig. 15.1. Drive system used on electric motor operated wheat threshers.

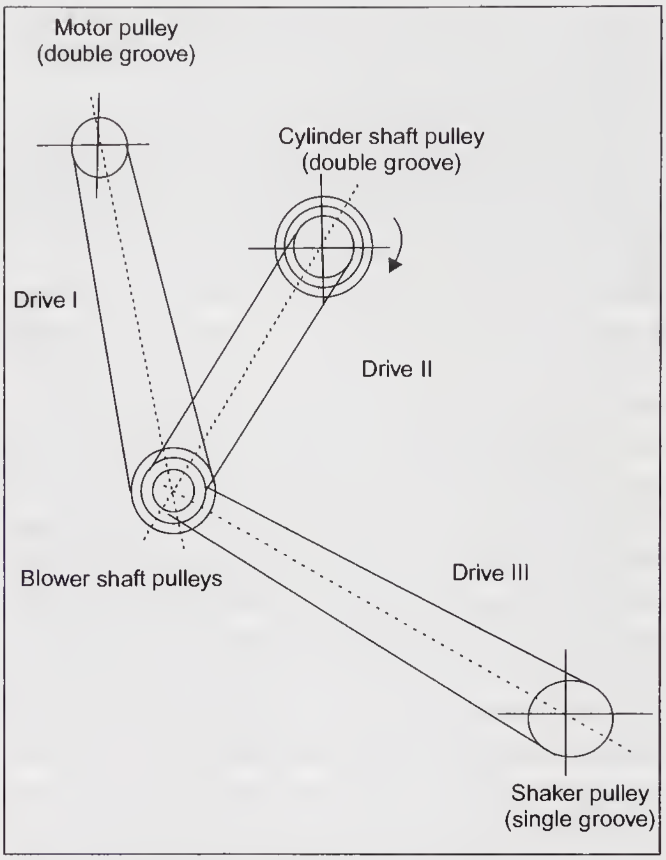

Fig. 15.2. Power transmission system used on CIAE multicrop thresher.

sizes of V- belts are available. The thresher size are mostly of 3.75kW. Therefore 60% of power is to be transmitted to threshing cylinder. The

Table 15.1. Setting of speeds of different units for threshing of different crops with CIAE multi-crop thresher.

Crop	Drive I - Motor to blower				Drive II - Blower to Cylinder				Drive III
	Motor Pulley in mm	Motor speed in rpm	Blower pulley in mm	Blower speed in rpm	Blower pulley in mm	Blower speed in rpm	Cylinder pulley in mm	Cylinder speed rpm	Blower to shaker
Wheat	125	1,440	225	800	200	800	200	800	Blower
Paddy	125	1,440	225	800	150	800	200	600	Pulley 100
Sorghum	125	1,440	225	800	150	800	250	480	mm
Maize	125	1,440	225	800	100	800	250	320	Shaker
Gram	125	1,440	225	800	150	800	250	480	Pulley
Gram ii	125	1,440	200	900	150	900	300	450	
Pigeon pea	125	1,440	225	800	100	800	250	320	225 mm
Soybean	125	1,440	225	800	100	800	300	266	Shaker
Soybean ii	125	1,440	200	900	100	900	300	300	speed
Sunflower	125	1,440	225	800	100	800	250	320	310-
Sunflower ii	125	1,440	250					350	400rpm
Safflower	125	1,440	225					350	
Rapeseed	125	1,440	250				300	350	
Mustard	125	1,440	250	700	200	700	200	700	

power transmitted to cleaning sieves is small. The power transmitted to aspiratory blower is in the range of 30-35%.

The power from main pulley on electric motor is transmitted to the unit that is operated at high speed, which is mostly the blower. From blower or from the motor it is transmitted to threshing cylinder and from here to the cleaning sieves and grain auger. The standard V belt drives are used to transmit the power using pulleys of suitable sizes. The standard belt sections of B size are used on the thresher as it is operated under dusty conditions and on the farm. In a typical wheat thresher the threshing cylinder and blower are mounted on the same shaft. Therefore the power is transmitted directly from motor to main shaft. The power to the cleaning sieves is transmitted by v-belt drive turned at 90 degree. As the power transmitted is of lower range, link type v-belt is used to take care of 90-degree rotation. The link type belt also eliminates the need of providing the idler.

Motor mountings

The motor frame is made adjustable type to suit different makes of motors with different mounting holes or slots. The belt drive for different units on thresher is designed on the basis of power to be supplied to the different units. The manufacturers supply the data on power transmitted by V-belts. However while selecting the size of belts for use on thresher the operating conditions are continuous type and machine are operated during hot dry and in dusty conditions. During rainy season the operation is also during humid conditions. The small threshers are mostly operated manually and there are chances of over loading the threshing unit by the farmers. The overloading can be 60 % or more. The drive design should take all these in account and the belt drive failure should not take place at least for 15 days of operation. The flat belts are also used on the threshers. The cost of flat belt is less compare to V- belts. The flat belts can be made of any size on the thresher by using belt connectors; whereas the V-belt of different sizes are to be stocked on the farm. The V-belts drive requires also the proper-machined pullies. Presently most of the thresher manufacturers are using V- belt drives. The belt drives are invariably provided with idlers to take care of belt slackness due to operation of machine. The belt elongation of 2-3 % is expected before replacement of the belts. When thresher is operated by electric motor, there are chances of voltage fluctuation in the supply line. This is because most of the farmers will be doing threshing operation at the same time resulting in voltage drop. Thus the speed fluctuations of electric motor are noted during the threshing season. Thus reduction in speed of + - 10 % should be mostly observed. The thresher performance should be within acceptable limits at those speeds. The safety precautions while using electric motor should be properly informed to the farmers. In three phase motors the direction of rotation on the threshing drum be properly indicated. Motor should be fitted with proper size switch or starter and be fitted with over load protection. The motor should be properly earthed and further with single-phase protection. The thresher and motor should be protected during wet season from rainwater.

The adjustments on thresher should be done only after power is switched off. The belt drives be covered with safety guards. They should be properly secured to prevent, there removal during operation. They should be rigid not to yield during rough handling on the farm.

The cable used for supplying the power to the motor should be of sufficient capacity to take care of high starting current.

The starter used for electric motor should have protection devices to prevent burning out of motors due to sudden fall in voltage or increase in current due to single phase supply.

The majority of threshers manufactured and marketed in India are electric motor

operated. These threshers are fitted with V- belt drive units. The spares for belts are available and farmers can also get them from the local market. In large size thresher the trend is to make them tractor p.t.o operated units. This makes them as portable machines and can be moved from one farm to other for custom hiring purpose. In case of rice crop the trend is to make motorized wire loop type drum fitted with small size motor to be operated on house hold supply. The farmers being economically weak can afford such type of threshers.

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16 Material of Construction

Materials used in manufacturing threshers 222

The production of threshers in many countries is made from mild or structural steel sections. Most of the components used are fabricated from mild steel. Thus with the use of a few simple machine tools and welding set, the fabrication of thresher is achieved. A numbers of parts are also made from cast iron. The ball bearings and V or flat belts used in drives are mostly standard bought out items. The body covers and trays are made from sheet metal or galvanized sheets. The shafts are mostly cold drawn round bars of proper sizes, which require minimum of machining or turning job.

Materials used in manufacturing threshers

The details of materials mostly used in fabrication of threshers are described below:

Main frame of thresher	Angle iron sections, channel or square tube or pipe
Feeding tray	Hot rolled mild steel sheet or galvanized sheet.
Threshing drum	Rolling of sheet to size of drum or mild steel flats are rolled in cylinder shape and provided with hubs at centre
Pegs for drum	M.S. rods or flats are hot forged to desired shape Medium carbon round bar are used as pegs. 12 mm size long bolts are used as pegs on the flats forming the cylinder.
Beaters	M. S. flats or round bars.
Concave	Mild steel round bars or square bars of 5 /6 mm size are used for the grate with spacing between bars varying from 6, 8, 10, 12 mm to take care of different crops. The sides of concave are provided with 10/12-gauge m.s. sheet for support.
Pulleys, flywheel, wheels, and bearing blocks	Gray cast iron castings. Bought as semi finished items.
Shafts for drum etc.	Bright bars or cold rolled steel
Blower blades and body	Mild steel hot rolled sheet.

Contd.

Sieves	Perforated sheets of 20 gauge thickness with holes of different sizes.
Hangers for sieves	mild steel hot forgings, cast iron
Covers, side and top	sheet metal reinforced with flats or angle sections.
Safety covers for drives	expanded metal or woven wire mesh
Bearings	Ball Bearings of standard make (NBC/ SKF/Timken etc.)
V- Belts	V- belts of standard A, B, C-sections. (Fenner Corp.)
Flat belts	Industrial grade type (Dunlop/ Fenner make) Procured as finished products.
Other parts used in fabrication are: Fasteners (nut and bolts) hinges, latches, Seals etc.	These items should be procured as finished products

Requirements which need attention of the manufacturers: These are as follows:

- Bearings on thresher are protected against ingress of dust and water.
- There should be positive arrangement for the lubrication of the moving parts.
- Safety covers are provided at the feed inlet to prevent accidents.
- Concave clearance should be easy to adjust.
- Belt lighteners are to be provided on the drives to take up the slackness from the drives.
- Sieves should be easy to replace and cleaned.
- Threshing drum is static and dynamically balanced.
- All parts of the thresher are coated with primer before painting.
- Direction of rotation of drum be properly indicated on the cover of drum etc.
- Drive covers should be strong to withstand rough handling.
- Operators manual be provided along with machine.

The spike tooth type thresher is the widely produced and used machine in India ever since its development at Allahabad Agricultural Institute at Naini, Allahabad, during 1964-65. It is manufactured at large scale by the small-scale industry in India. The present production is estimated around 500,000 units per year. The total population in India is estimated at 5 million units. These threshers are used for threshing of most of the crops except the rice crop for which the machine is modified or loop tooth type threshing drums are used.

Materials for spike teeth: Das (1995) predicted the production of one million threshers in the country. Among the thresher the spikes are the parts, which wear most during the operation. The survey showed that mild steel spikes wear out during the threshing of 150 tonnes of grain. This is about 2 to 3 year of use by the farmer for threshing crops. The numbers of spikes used on wheat threshers vary from 36 to 72 from 3 hp to 15 hp size machines. The average number of spikes used on 5 hp threshers is 46 in number. The three types of spikes used are round bar, rectangular or square type. The round type spikes are with and without threading either full or partially threaded. The size of spike is 15/16 mm in diameter and 125 mm long. The trials at CIAE indicated rectangular flat type spikes resulted in better quality of bruised straw. The rectangular spikes are 38 x 9.5/10 mm size and 125 mm long. Thus pegs are the most worn out part on thresher.

To over come wear of spikes and increase their life the material recommended is carbon steel of C 50 or (EN 43A) the part made is to

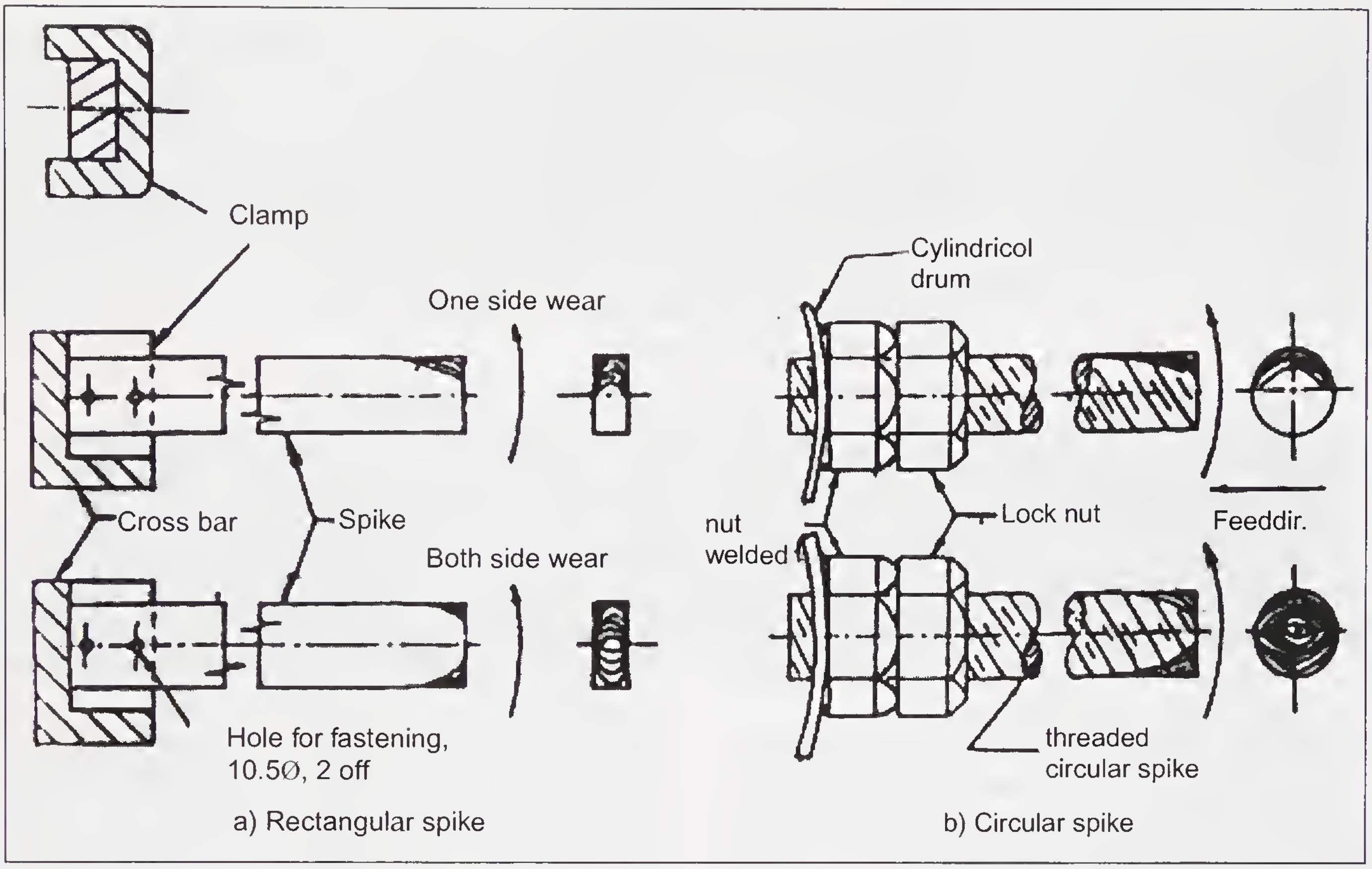

Fig.16.1. Wear pattern of spikes used on threshers in India.

be hardened and tempered to HRC-40. They are also made from the scrap automotive leaf springs. The leaf spring flats are annealed for making the pegs and spikes are hardened and tempered. In round bar the wear is on the one side and by changing the side longer life is achieved. In case of round spikes a simple induction hardening can be employed to harden the threshing tip portion of spike.

Spikes for combine cylinder: The possibility of using spikes of conventional combines for rice threshing was studied by Sandhar, *et al.* (1984) for threshing of wheat crop on wheat threshers. The variables included the axial distance between spikes, cylinder speed and feed rate. The performance was determined in terms of threshing efficiency, grain crackage and power requirements. It was reported that for the axial distance of 75 mm between spikes resulted in threshing efficiency of 99 %, grain crackage within 2% for the various threshing speeds (24, 27, 31mps) used for wheat crop. Thus it was concluded that spikes used on rice cylinder can be used also on wheat threshers.

For the thresher manufacture the aim is to use the easily available materials to produce the machines at the least possible cost so that he can pass on the savings on cost to the farmers. However even the farmers are aware of the use of quality components on the machines. This helps them to have trouble free performance from the machine. Normally there should not be any failure for the two crop seasons at the farm level. The manufacturers who produce quality machine are benefited immensely as the customer is their advertising agent in the region.

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17 Testing Procedures of Threshers

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Threshers are being manufactured in large numbers and used in the country with the fast mechanization of agriculture in south and South East Asian countries. The commercial availability of machines is also helping the farmers to use these machines for threshing most of the crops. The thresher is a machine to thresh the crop to recover the grain or seed and straw in the desired form as required by the farmers and with minimum of grain losses and also the minimum of grain damage. The machine should have sufficient capacity to do the job timely and at a cost, which is lower than that by traditional methods of threshing. It should also be energy efficient. Though it has been proved that most of thresher manufactured and supplied to the farmer are capable of doing the job efficiently still there are many fabricators who pay little attention to quality and the safety features on the machines. It is also noted that many small fabricators even do not supply the 'Operators Manual" to purchaser of machine. Thus lack of information and inadequate safety measures do cause accidents leading to the loss of limbs of operators. The testing of thresher can provide the buyer the information about the performance of machine under normal operating conditions on the farm. For testing of machine it is important for the manufacturer to provide all the information and specifications of the machine. He has also to explain the adjustments provided and method of doing them properly. This would ensure a safer and superior machines for the users.

The performance of thresher also depends

on the crop conditions, machine settings and adjustments and also the design features of threshing units used. Many times it is noted that Indian farmers would like to have straw as in bruised form or in full form as it has either economic value and is used as animal feed. Thus the wheat thresher designed for making *bhusa* may not be useful to rice farmers who want straw in undamaged form. To make machine more efficient the tests are to be carried out to check its performance and compare it with other machines or designs.

Therefore it is desirable to have the standard test procedures and methodology to determine the performance of machines and critically analyze them from the users point view or the designers point to make better and more efficient machines.

Before testing a machine, it is necessary to define the terms used in describing the various parameters and the methods used to observe or record the observations. Thus the testing procedures involves definition of terms, the instrumentation required to take observations, to plan the different types of tests, viz. the long and short duration tests, and recording of test observations. All these topics are covered in this chapter.

Terminology used

The definitions of various terms used while conducting tests or study of power thresher as given below:

Broken grain: Wholly or partially cracked or broken grain.

Clean grain: The threshed grain free from foreign or broken grain.

Cleaning efficiency: Clean grain received at the main outlet with respect to the total grain mixture received at the main grain outlet expressed as percentage.

Concave clearance: The clearance between cylinder drum tip and the concave normally measured at the lower point.

Feed rate: The quantity of crop fed into the inlet of thresher per unit time.

Foreign matter: It includes inorganic and organic matters. The inorganic matter comprises of sand or soil particles, pebbles, mud, etc collected during harvesting of crop. The organic matter comprises of chaff, straw, weed seed and other crop grains.

Grain mixture: The mixture of clean, broken, unthreshed grain and foreign matter coming out of the grain outlet of thresher.

Maximum input capacity: The maximum feed rate at which no choking occurs in the thresher and no stalling occurs in the prime mover at the speed specified by the manufacturer.

Optimal input capacity: The maximum feed rate at which efficiencies are within the specified limits of the relevant Indian standards.

Output capacity: The mass of the grain mixture received at the main grain outlet when collected at optimal input capacity.

Percentage of blown grain: The clean grain lost along with chaff/straw with respect to total grain mixture received at the main grain outlet expressed as percentage by mass.

Percentage of spilled grain: The clean grain dropped through the sieve and over-flown from sieve along with tailings with respect to total grain input. It is expressed as percentage by mass.

Percentage of unthreshed grain: The unthreshed grain from all the outlets with respect to total grain input, expressed as percentage by mass.

Power thresher: A machine operated by a prime mover to separate the grain from harvested plant.

Prime mover: A machine used to operate the thresher such as an electric motor, tractor or an engine.

Rated optimal capacity: 75% of the maximum input capacity when expressed in quintals per unit of time to determine the desired test data.

Routine test: Test carried out on each thresher to check the requirements, which are

likely to vary during production of machine.

Sample: The quantity of grain or straw taken from an outlet for a specified period of time.

Screen slope: Inclination of screen with the horizontal plane in degrees.

Sieve clearance: The vertical distance between two successive sieves.

Threshing efficiency: The threshed grain received from all outlets with respect to total grain input expressed as percentage by mass.

Type test: Test carried out on the thresher to ascertain conformity with requirements of the relevant Indian standards. These are intended to ascertain the general qualities and design of a particular type of thresher.

Unthreshed grain: Grain collected from unthreshed heads.

Machine requirements:

- Marking of direction of rotation of threshing unit,
- Marking of feed inlet and grain outlets,
- Safety arrangements and covers provided at moving parts,
- Provision of lubrication of moving parts and bearings,
- Provision of belt tightening arrangement,
- Provision for transportation of machine on farm and road,
- Provision of easy replacement of cleaning screens,
- Provision for changing of cylinder and blower speeds,
- Balancing of moving and parts,
- Parts of thresher are protected against corrosion.

Adjustments on threshers:

- Feed rate,
- Concave clearance,
- Speed of cylinder, blower and screens,
- Screen slope,
- Sieve clearance, and
- Air blast.

Performance requirement as per ISI standards:

- The capacity of thresher shall not be less than 85 kg of wheat per kWh energy consumed.
- The threshing efficiency shall not be less than 99%.
- The cleaning efficiency shall not be less than 96%.
- Total losses shall not exceed 5% in which cracked grain shall not be more than 2%.

Selection and specification of thresher for test

The power thresher shall be taken from the series production by the testing authority with the consent of manufacturer for commercial testing.

Specifications and other literature

The manufacturer shall supply the literature; operational manual and schematic diagram flow of the material for the thresher. The specification sheet is also filled up as shown. He should supply any further information, which might be required to carry out the tests. The manufacture should give maximum input capacity, optimal input capacity and output capacity of the thresher and the names of crops which can be threshed and any adjustments required to be made for the same.

Specification sheet of the thresher

Tools, accessories and manual are provided with the thresher.

1. General (To be filled in by manufacturer and supplied to testing station)
   Make
   Model
   Type
   Year of manufacture
2. Power unit
   Provision
   Type of prime mover
   Recommended power, kW or hp

Type of drive

3. Main drive
   Type
   Size of belt
   Size of pulley
   Diameter of main shaft
4. Threshing unit
   Type
   Constructional features
   Diameter
   Width
   Recommended speed
   Number and size of beaters/ bars/ projections
   Number and type of bearings
5. Concave
   Type
   Diameter or width
   Length
   Concave clearance range
   Recommended concave clearance
   Method of adjustment
   Constructional features
   Method of fixing
   Angle of sliding pan
6. Sieve
   Type
   Number
   Total length and width
   Effective length and width
   Number of holes per sq cm
   Size of hole
   Sieve clearance
   Screen slope range
   Recommended screen slope
7. Shaker
   Type
   Number of strokes per minute
   Drive
   Number and type of bearings
8. Elevator
   Type
   Constructional details
   Capacity
   Drive
   Grain spout size
   Height above ground level
   Number and type of bearings
9. Blower
   Number
   Type
   Number of blades
   Size of blades
   Diameter
   Recommended speed
   Recommended air displacement
   Provision of changing air displacement
   Size of inlet opening
   Drive
   Number and type of bearings installed.
10. Crop feeding
    Type
    Method
    Size of feeding chute
    Height and location of feeding chute
    Recommended maximum feed rate
11. Drum
    Constructional features
    Number of projections
12. Transport
    Type
    Number of wheels
    Wheel bearing
    Type of towing arrangement
13. Flywheel size
    Diameter
    Weight
14. Overall dimensions
    Length
    Width
    Height
15. Ground clearance
16. Total mass

Note 1: The items, which are not applicable in a particular thresher, should be crossed while filling in the details.

Note 2: If any other items are provided their details should be filled in.

Instrumentation required for testing of thresher

The list of instruments for testing of thresher is given below:

Name of instrument	Size	Purpose
Steel scale	100 cm	For measurement of crop length
Steel tape	3 m	For measurement of machine parameters
Dial calipers	0-30 cm	For measurement of crop stem diameter
Balance for weighing	0-250 g with Least Count of 0.001g	For weighing the grain samples broken, unthreshed grains etc. including samples collected from grain outlet, straw outlet etc.
Weighing balance	0-5 kg Least Count 1.0 g	For weighing samples from grain outlet and straw/grain ratio
Weighing balance	0-300 kg LC- 100g	For determining input output capacity
Temperature recorder	0-100 degrees C L.C. 0.5 deg.	For measurement of ambient temperature
Stop watch	0-15 min L.C. 0.1 sec.	For measurement of time
Hand tachometer	0-2000 rpm	For measurement of speed of rotating parts
Anemometer	0-15 m/s	For measuring the air velocity
Abney level	0-90 L.C.-0.1	For measurement of slopes of sieves
Watt meter	0-8 kW L.C.-100 Watts	For measurement of power
Electrical energy meter	0-10000 kWh L.C.-.01kWh	For energy measurement
Hot air oven	0-200 C	For determining moisture level of grain and straw

L.C. means Least Count.

Note: The thresher shall be provided electric power through starter, wattmeter and energy meter in series for measurement of power and energy consumption. The instruments are required to be calibrated before use during tests.

Pre-test observations

Determination of straw and grain ratio and moisture contents is to be carried out as follows. Take five samples of the crops each weighing about one kilogram. Separate the grains from straw manually for each sample. Take the mass of grain and straw separately and calculate their ratios. The average of five samples shall be taken as straw grain ratio.

Moisture content of grain and straw: Take five samples of grain and straw for moisture level tests. The samples should be tested in accordance with IS: 4333 (Part II)-1967.

Running in and preliminary adjustments: Before commencing tests, the machine shall be placed on the clean, horizontal surface and properly anchored to the ground. The manufacturer in collaboration with the testing authority shall run the power thresher –in for at least one hour. The adjustments for the speed of different shafts, concave clearance, speed of prime mover, screen slope etc; be done as per the manufacturers recommendations.

Test procedure: The testing of power thresher involves three types of tests to be carried out as follows:

- Test at no load,
- Test at load for short duration, and
- Test at load for long duration.

(1) Test at no load will be conducted at the recommended speeds for threshing specified crops without any load at least for ten minutes to observe the power consumption of the moving parts of the machine.

(2) Test at load for short duration (one hour test) will be conducted at four different feed rates (maximum feed rate, 75% of

max. feed rate, 50% of max. feed rate, 65% of the max. feed rate) and two different speeds (15% more and 15% less than recommended speed) of one-hour duration each to evaluate the performance of the machine.

The cylinder speed at varying feed rate will be recommended speed and feed rate at varying speed will be 75% of maximum feed rate. For each test, parameters related to crop, machine, operating conditions and ambient conditions are to be recorded. The parameters related to the performance of the machine are to be recorded as given below.

Speed of moving parts: The speed of rotating parts shall be observed by hand tachometer or revolution counter thrice during each test and average values shall be reported. For testing at different speeds, speed of the machine may be varied by changing pulleys at motor or cylinder shaft or both.

Feed rate: Sufficient number of crop samples of 25 kg each shall be weighed by platform balance and kept ready near the machine before the start. The maximum feed rate at which no choking of cylinder/blower/ sieve occurred at the recommended speed shall be determined initially and feed rate shall be controlled by regulating the quality of crop to be fed in pre calculated time. The operator shall be trained 3-4 days before conducting tests to get acquainted with the test procedures.

Energy consumption: For measurement of power required to operate the thresher shall be driven by a single/3 phase electric motor having rated power as recommended by the manufacturer or designer. For measurement of energy consumption, suitable energy meter shall be used.

Power consumption: Power requirement shall be observed several time during test by connecting suitable watt meter and minimum, maximum and average readings are to be recorded.

Samples collection during tests: During each test, three samples shall be collected at 20 minutes interval from main grain outlet for 30 seconds sieve overflow outlet (30sec) and blower outlet (15 sec) by using sampling bags and a nylon mosquito net for collecting blower outlet samples. Stopwatch is used for recording time. Later on, unthreshed grain, broken grain, clean grain and foreign material shall be separated from each sample manually and weighed by precision balance. The total grain mixture collected at the sieve underflow shall be analyzed as above. The grain and straw moisture should be determined in accordance with IS: 4333 Part II.

Calculations for performance data: Percentage of broken grain = C / A x 100

Where A = B+C+D

= Total grain input per unit time in kg;

B = weight of clean grain from all outlets per unit time (kg);

C = weight of broken grains from all outlets per unit time (kg); and

D = weight of unthreshed grains from all the outlets per unit time (kg).

Percentage of blown grain = G/A × 100

Where G = weight of clean grain obtained at blower outlet per unit time (kg)

Percentage of unthreshed grain = D/A × 100.

Percent of spilled grain = K/A v 100

Where K, weight of clean grain obtained at the sieve overflow and under flow per unit time (kg).

Threshing efficiency = 100- percentage of unthreshed grain

Cleaning efficiency = M/F × 100

Where M, weight of clean grain in above sample (kg); F, weight of sample in the main grain outlet per unit time (kg).

Output capacity = total weight of the threshed grain received at the main grain outlet per hour.

Long Run Test

For long time trial, the thresher is operated

for at least 50 hours at load which should be covered by continuous run of at least 5-hour duration. The major breakdowns, defects developed and repairs made are recorded.

Observations are to be made during each long run test as follows:

- Presence of any marked oscillation during operation,
- Presence of undue knocking and rattling sound,
- Slippage of belts and their frequency,
- Smooth running of shafts in the bearings,
- Frequency of clogging of threshing unit,
- Clogging of sieve apertures,
- Smooth flow of material through different components,
- Vibration free running of fan,
- Marked rise in bearing temperature,
- Any marked wear deformation and breakdown,
- Loosening of fasteners,
- Other observations if any, and
- Stoppage of thresher for repairs (minutes).

Interpretation of data

Interpretation of data is not required for routine test. It is required for research study where critical analysis is done.

All data related to crop, machine, and operation and tests for a particular crop are recorded on DATA SHEET as shown in Tables 17.1, 17.2 and 17.3. These data are to be analyzed and Table 17.1 is prepared for each crop, summary of test results for different crops will be reported as per Table 17.2 and economical analysis is done as per Table 17.3. On the basis of tests, required performance curves are drawn for feed rate vs. efficiencies, losses and power consumption and cylinder speed vs. efficiency, losses and power consumption. On the basis of test results and observations, comments are to be made on specific power requirement, output losses, quality of grain and straw.

Test report

On the basis of tests, engineer should prepare a brief report including the Tables, graphs and charts to show the effect of various parameters. He should give a summary and write conclusions to highlight the best features of machine and the defects noted during long duration tests.

Table 17.1. Short duration test results of thresher under test

Description	Max feed rate in kg/min.	75% feed rate in kg/min.	50% feed rate in kg/min	65% feed rate in kg/min	15% More speed and 75% feed rate	15% less speed and 75% of feed rate
Crop factors						
Crop and variety						
Date of threshing						
Straw grain ratio %						
Straw moisture %						
Grain moisture %						
Operational data						
No. of persons used						
Ambient temp. (˚ C)						
Wind velocity (m/sec)						

Table Contd.

Table 17.1. *Concluded*

Description	Max feed rate in kg/ min.	75% feed rate in kg/ min.	50% feed rate in kg/ min	65% feed rate in kg/ min	15% More speed and 75% feed rate	15% less speed and 75% of feed rate
Actual operation (h)						
Blower outlet velocity (m/sec)						
Feed rate (kg/h)						
No load power (kW)						
Power required (kW)						
Energy consumption (kWh)						
Performance data						
Broken grain (%)						
Blown grain (%)						
Spilled grain (%)						
Total grain loss(%)						
Threshing efficiency %						
Cleaning efficiency %						
Output capacity (kg/h)						
Cost of operation (₹/tonne)						

Table 17.2. Summary of test results

Item	Crop
Crop variety	
Grain straw ratio	
Straw moisture (%)	
Grain moisture (%)	
Cylinder speed (m/sec)	
Feed rate (kg/h)	
Energy consumption (kWh)	
Blown grain (%)	
Broken grain (%)	
Spilled grain (%)	
Total grain loss (%)	
Threshing efficiency (%)	
Cleaning efficiency (%)	
Output capacity (kg/h)	
Cost of operation (₹/h)	
Cost of operation per tonne of grain in ₹	

Table 17.3. Comparative Statement of performance values of threshers tested

Capacity (kg/h)	Crop	Crop	Crop	Crop
Machine A				
Machine B				
Machine C				
Losses (%)				
Machine A				
Machine B				
Machine C				
Cleaning (%)				
Machine A				
Machine B				
Machine C				
Energy / power				
Consumption per tonne of grain (kWh)				
Machine A				
Machine B				
Machine C				
Cost of operation per tonne of grain (₹)				
Machine A				
Machine B				
Machine C				

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18 Ergonomic Studies

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Ergonomics is defined as the scientific study of the relationship between man, machine and his working environment. The working environment includes the ambient conditions, tools and materials handled and method of work and its organization. The man as a source of power has very limited power but by controlling power and machines has got unlimited capabilities. Therefore, the capacity and limitations of human being are studied and given due consideration so that the comfort, health, efficiency and safety are maximized. Thus the main goal of ergonomics is to heighten the quality of life in work places in all walks of life. Ergonomics is a multi disciplinary approach with the objective to have maximum operational efficiency. The disciplines involved are anatomy, physiology, anthropometrics, physiological psychology, experimental psychology, industrial medicine, physics and statistics. The overall objective is to increase efficiency of human activity by providing data, which will enable to make correct decisions. In doing any job, a man must be organized so that he can maintain maximum efficiency and interest and utilizes his abilities fully.

In any activity the operator or worker receives and processes the information and acts upon it. The first of these, the receptor functions occurs largely through the sense organs such as eyes, ears, through the sense of smell, touch or feel. This information is processed at the brain and spinal cord and decision is arrived. The individual then takes action as a result of the decision and does the activity through his effectors' mechanism involving muscular activity based on the skeletal frame work of body. In a way he forms a part of a closed loop servo-system involving many feed back characteristics of a system. His work must be organized so that he attains the maximum efficiency and interest and his abilities are fully utilized. In corporation of human factors in the design of machine allows the operator to perform tasks with efficiency, comfort and safety.

Human factors verses design approach

For the design of agricultural equipment or tool, the factors to be considered for efficient and safe operation of machine are:

- Determination of visual requirements for the maximum efficiency, therefore, the position of operator should be so placed that he can have optimum vision of functioning and other display.
- The posture of the operator during working situation viz. sitting, standing or squatting while performing the activity with the tool or machine.
- Placement of controls as near as possible to the optimum areas near or on the equipment being operated.
- Arrangement of the spacing, direction of movement, size, colour and shape of controls.
- Work environments created by the machine during its operation for the safety of operator and his health.

Modification of design

Once the machine achieves the operational requirement of the farmers, there are reasons for the modifications in the design based on ergonomic considerations for the operators as the machines are to be operated by a wide range of workers. These are related to:

- Reduction in physical and mental work loads on the operator so that the efficiency of machine is improved.
- Minimizing accidents involving operator, equipment or crop and to provide protection to the operator against an occurrence of accident.
- Making machine suitable to be operated for a longer period or continuously.

Ergonomic assessment of design

The assessment of design of machine involves three stages

1. Initial level of development of machine. This is to be done by a person experienced in ergonomics.
2. Performance assessment of equipment which is likely to be affected by ergonomic considerations should not be overlooked. As there is variability with regard to person to person, as training and familiarity with a particular machine great care must be taken.
3. Subjective opinions of the users or observers are important data, as these are affected by many external factors, need to be considered.

In India traditional agriculture utilizes mainly the manual and animal power. However, the trend has changed and mechanical power is being used on large scale. The equipment or machines for different agricultural operations suitable for manual, animal and power are commercially available and are being improved or developed by various organizations. For design of equipment, it is necessary to give due consideration to the anthropometrical and strength data of agricultural workers so as to have enhanced performance along with better comfort and safety of operators. In mechanization of agricultural operations being carried out manually, the attention is being paid to improve the energy expenditure in performing certain tasks, the work postures and efficient handling of tools and also the safety of the operator. In agricultural operations the work situations involved are of many types and work posture during operation can reduce the physiological load on the operator. Therefore, in design of manually operated tools and machines, the comfort of the operator must be given due considerations.

Work load

The expenditure of energy in performing physical work is quantified by indirect measurement of the rate of oxidation processes in which the worker converts the carbohydrates, fat and protein into energy. The rate of consumption of oxygen in this process is measured as the difference between quantities of oxygen inspires and expired by

the body during the work. Only a portion of the energy appears to be useful mechanical work, the remainder being dissipated in heat. The other physiological factors as heart rate (HR), Pulmonary ventilation rate (PVR), and respiration rate (RP) can also be linked with the mechanical work output.

The human energy measurement for different agricultural operation under local environment conditions can be done with a loading device viz. bicycle ergo meter and treadmill through the measurement of physiological parameter corresponding to mechanical work output. In other terms, the human effort is expressed in terms of physiological response, which is termed as the calibration of the subject. The bicycle ergo meter is basically a bicycle modified in a way that the rear wheel is heavy one to act as the flywheel and the front wheel is removed. This modified bicycle is mounted on the frame. The load on the rear wheel can be varied by varying the tension of a band on the rear wheel, which can be used by mounting two spring balances. The mechanical work output can be measured as follows

$$PS = \frac{\pi \times D\,(T_1 - T_2)\,N}{4500} \tag{18.1}$$

Where, $T_1 - T_2$ = load on the rear wheel (kg); D, diameter of rear wheel (m); and N, rpm of the wheel.

Corresponding to this mechanical work output, the physiological parameters(HR, PVR, RR and O_2 consumption are measured. After giving proper rest to subject, the load is varied and the corresponding mechanical work outputs are plotted and the straight line serves as the calibration curve. In the cycle ergo meter the main limitation is that it does not simulate the natural posture because of the foot cranking. The lower body is in motion and there is very limited movement of the upper body. Therefore presently treadmill is considered as the better equipment for the purpose of calibration since it simulates the natural movement of body. The treadmill consists of an endless belt conveyor whose speed and grade can be varied. The mechanical work output is calculated as follows:

$$PS = \frac{W \times V \sin \Phi}{4500} \tag{18.2}$$

W, weight of subject (kg); V, linear speed of the belt conveyor (m/min); and Φ = angle of belt conveyor with the horizontal.

Treadmill can therefore be used with greater advantage to obtain relationship between different physiological parameters. Physical work rate is normally quoted in kcal/min. Christenen has proposed a relationship between energy expenditure in calories, the heart rate and subjective scaling of work heaviness. The qualitative assessment of the workload is helpful in the design modification to suit the operators.

Review of literature

Manuaba (1976) reported that a particular type of hand hoe with 1.53 m handle length was identified as the most efficient tool in terms of work done and heart rate level reported. Sen (1984) illustrated how a shovel with an additional handle could reduce the strain and increase the efficiency of the worker. Nag and Dutt (1979) studying the oxygen uptake and pulse rate changes of farm workers recommended a wheel hoe type weeder as the most efficient implement for the Indian farm. In performing farming operations, it was noted that the Indian workers are generally required to perform heavy work. Nag *et al.* (1980) reported that pedal operated paddy thresher and bund trimming in rice crop production were extremely heavy type of operations (Table 18.1).

Maximum aerobic capacity of farm workers

Maximum aerobic capacity also called the maximum oxygen uptake capacity or VO_2 max is conceived as an international reference standard of cardio-respiratory fitness. The VO_2

Table 18.1. Physiological responses of male workers in performing different farm operations. (*Source:* Gite and Singh, 1997)

Operations	Physiological Responses		Source
	Heart rate beats/min	Oxygen uptake (VO_2), l/min	
Digging soil with pick axe bending posture	155.2	-	Kaul and Splinter (1964)
Ploughing with country plough standing posture	131.2	0.997	Nag *et al.* (1980)
Fertilizer broadcasting by hand standing posture	126.3	0.433	Nag *et al.* (1980)
Uprooting weeds in bending posture	114	0.578	Nag et al. (1980)
Uprooting weeds in sitting posture	113.3	0.573	Nag and Dutt (1979)
Rice threshing by beating	135.8	0.920	Nag and Dutt (1980)
Threshing with pedal thresher	140.8	1.310	Nag and Dutt (1980)
Winnowing in standing condition (traditional)	124.3	0.808	Nag and Dutt (1980)
Groundnut decortications with standing posture	107.2	0.656	Singh (1993)
Keeping watch and scaring birds	75.5	0.214	Nag *et al.* (1980)

Note: While working on farm for eight hours duration, the activity requiring oxygen consumption of less than 0.7 l/min is considered as the acceptable level. The corresponding heart rate for this oxygen consumption level is around 100-105 beats per min. Thus for Indian workers, the load created by operating tools or machines should be within the above range of heart beats.

max is dependent on many factors such as race, age, sex, body built up and training etc. For workers in developed countries it ranges from 3.5 to 4.5 l/min (Astrand and Rodhal, 1977). In contrast the values for VO_2 for Indian and Asian workers are about 2.0 l/min. Thus it can be seen that there is a large difference between the maximum aerobic capacity of Indian and western workers. For women the maximum aerobic capacity is about 70–75% of that of men.

The studies conducted at TamilNadu Agricultural University on male and female workers in performing various agricultural operations to determine the energy expenditure in performing the various tasks. It was reported that most of the farm operations performed for cultivation of rice crop were rated as moderately heavy and energy expenditure was in the range of 4.0kcal/min. Table 18.2 gives the energy consumption by the operator in performing the field operations.

Energy expenditure during farm operations

The energy expenditure in the agricultural machine operations has been compiled by Gite by reviewing the work of many research workers. The values reported for various operations are reported in Table 18.2.

Body dimensions of farm workers

Further the machines should be suitable for the workers of varying age and body dimensions. The body dimensions collected and analyzed for the agricultural workers from 12 states of India by Gite, reported that the mean height and weight of agricultural worker worked out to be 163.3 ± 6.8 cm and 54.7 ± 8.7 kg for male workers and 151.5 ± 6.1 and 46.3 ±7.8 kg for female workers. The age of workers varied from 16 to 65 years. The mean value of push strength with both hands

Table 18.2. Energy expenditure in performing agricultural operations on farms

Farm operation	Energy expenditure in kJ/min	Source
Digging of soil with spade	22.5	Nag *et al.* 1980
Ploughing with animal drawn plough	22.96	Nag *et al.* 1980
Seeding with manual seeder in wetland	33.4	Nag and Dutt (1980)
Keeping watch to scare birds	4.49	Nag *et al.* (1980)
Rice threshing by beating	19.26	Nag *et al.* (1980)
Rice threshing with pedal thresher	27.56	Nag *et al.* (1980)
Winnowing, standing	17.06	Nag *et al.* (1980)
Decorticating groundnuts	13.73	Singh (1993)

Note: The limit for acceptable workload for Indian workers according to Saha *et al.* (1979) was considered as 14.6 kJ/min.

in standing posture was 224 ± 56 N for male and 143 ± 39 N for female workers.

Application of ergonomics

The criteria for ergonomic design of threshing, shelling, decorticating and cleaning machines and tools should incorporate the capabilities of human worker. It should use the proper posture of the operator for most efficient performance of the machine at a lesser level of fatigue. The ergonomic evaluation was conducted on tools and machines developed at CIAE, Bhopal during 1980-90, to take care of varying body dimensions, strength levels of workers spread over the country as the prototypes were to be supplied to various extension agencies. The attention has been paid to most of the manually operated tools and machines used by the farmers. The machines for threshing, stripping, shelling, decorticating and cleaning are covered to highlight the application.

Design of safe feeding chute

The feeding chutes on the chaff cutter type wheat threshers are fitted with feeding rollers and the rollers are powered with gear drive. Many times the feeding hopper of wheat threshers was not properly covered with sheet cover. Because of lack of this safety features, large number of accidents were occurring on the farms where the farmers/ workers lost their limbs during the threshing seasons during 1979-80 in the state of Punjab and Haryana. Therefore through an act of Indian Parliament, it was made compulsory to provide safe feeding chute on the wheat threshers and also provide insurance coverage to farm workers during 1980-81. The major criteria for safe feeding chute was to keep its length long enough so that the fingers or hand must not touch the feeding rollers or beaters of the threshing drum during operation. Further to avoid accidents in case the farmer intends to feed the crop from the top or side of feeding chute, the top portion of the chute be covered so that the fingers should not touch any of the moving parts when the arm of the operator is bent at the elbow. The base of chute and top were given slope and tapered so that crop can be fed easily in the machine or threshing cylinder. Thus dimensions of feeding chute were standardized and are given in the Table 12.4 and the shapes are shown in Fig.18.1.

The dimensions B, D shall be 900 mm. (minimum), 450 mm (min). The value of angles shall be 10 to 15 degrees for hammer mill and drummy type and 0-5 degrees for chaff cutter type and –10 to+15 degrees for spike tooth type.

This was the first design taken seriously and adopted by the manufacturers of wheat threshers to adopt on their machines to safe guard the interest of farm workers in India. It was made compulsory by an act of parliament for the owner of the thresher to have safe feeding chute installed and also have insurance for the operator against accidents. It was also made compulsory for the manufacturers to

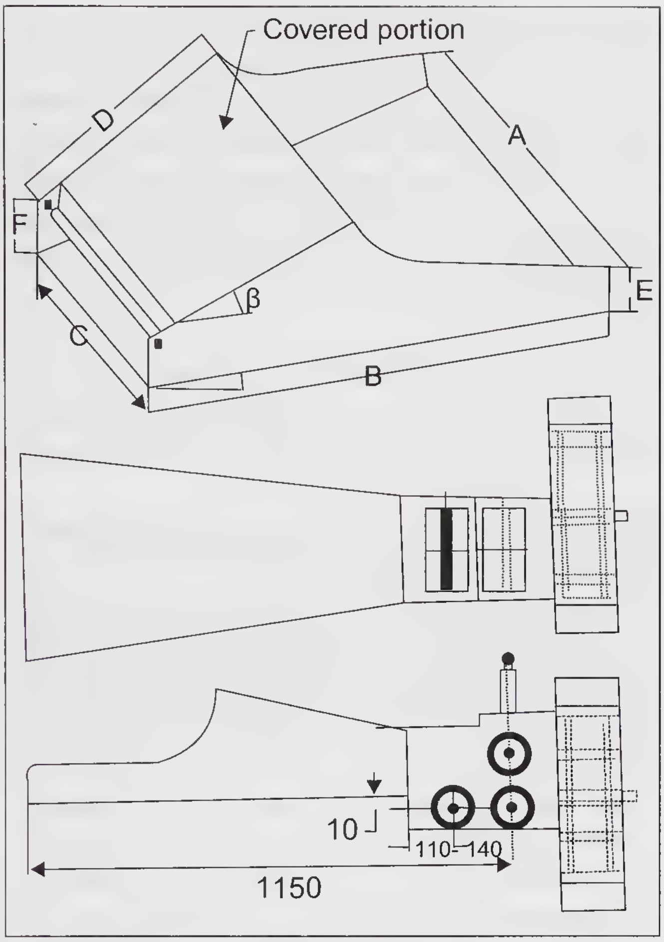


Fig. 18.1. Safe feeding chutes for power operated threshers.

adopt modified feeding chute on their thresher before selling the product in the market thus simple change reduced the thresher accidents to a great extent. The above fact emphasized the need of collecting anthropometrics data of farm workers of different states in India.

Ergonomic studies on tubular maize sheller

The tubular maize sheller available is basically of three shapes. It is made from M.S. tube of 62.0 mm diameter inside which four tapered ribs made from sheet metal are riveted. The second design is a tube of octagonal shape where the ribs are integral part of the strips from which octagonal shape is given. This design was developed to reduce the cost of sheller as metal tube is costlier compared to sheet for its fabrication. In the third design the fins are serrated so as to help in operation and shelling of grain. (Fig.18.3). The study was conducted at Marathawada Agricultural University, Parbhani in 2003-4. The three shellers were designated as MS1, MS2, and MS3 with difference in shape and fins for shelling cobs. The cobs of sweet corn variety at 18% moisture content were used for evaluation. The length and circumference of cobs were 21 and 15.2 cm respectively. The five female workers in the age group of 27 to 35 were selected for the trial. The anthropometric data of subjects were recorded. The heart rates of the subjects during trial were measured by Polar heart rate monitor (model S 810).

The studies were conducted using female farm workers to study the physiological load on such workers. The body part discomfort, the increase in heart rate (ΔHR) beats/min= (Heart rate during work-heart rate during rest) and Increase in heart beats/kg of grain shelled = [ΔHR, beats/min/output kg/h] × 60.

The body parts of workers, reported to

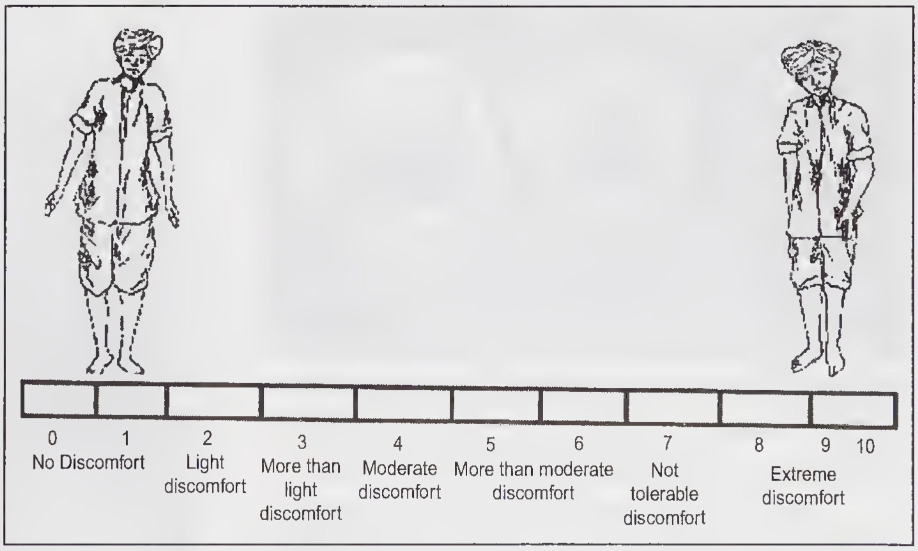


Fig.18.2. Analogue scale used for measuring the level of discomfort to the worker during shelling (*Source:* Corelett and Bishop, 1976)

suffer discomfort were left palm, right palm, right wrist, left wrist, right forearm, right shoulder, mid back and lower back. The level of discomfort was assessed using the overall discomfort rating a 10-point visual Analogue Scale with value of 0 as no discomfort and 10 as extreme discomfort as used by Corlett and Bishop (1976). The overall discomfort rating given by each subject were added and averaged to get the mean rating. The body part discomfort score for the three shellers were nearly same and score was 51. As regards to overall discomfort rating the tiredness rating was more for the first maize sheller than the two other shellers (2 and 3). Some discomfort was felt in both hands, wrists, and fore arms whereas more discomfort in left palm.

The mean heart rate values of the subjects while shelling with the three shellers were 109.55, 105.02 and 103.04 beats/min respectively. This value of heart beat is considered as an acceptable workload for the farm workers. As per Astrand and Rodhal (1977) heart beats in the range of 90-110 beats/min is graded as moderate. It was reported that tubular maize sheller with serrated fins had high shelling rate of 25.2 kg/h compared to 23.4 and 22.8 kg/h for the other two units. The workload on worker was rated as moderate workload.

Fig.18.3. Three tubular maize shellers evaluated at Parbhani.

It was concluded that the performance of tubular maize sheller could be improved by improving by removing the plain tapered fins with serrated fins. The study also pointed out that even though workload may be low but the operator can feel the fatigue or pain in his limbs used in the activity. (wrists and palms as the sheller is held and twisted by the worker). Reduction of shelling output would help in reducing the work stress. In case of handling larger quantity, the method of shelling is to be changed.

Use of dynapod for maize shelling

CIAE, Bhopal has developed a dynapod based on the anthropometrics consideration

Table 18.3. Performance of rotary maize sheller in two modes of operation

Performance parameter	Value for hand cranking method	Pedal operation using dynapod
Avg. operating speed, (rpm)	54.2	68.6
Mean heart rate of worker (beats/min)	140	116
Time for shelling 50 kg sample (min.)	16.9	10.6
Shelling capacity kg of cobs/h	177.6	282.7
Shelling capacity in kg of grain/h	145	231
Shelling efficiency	98.5	98.5
Grain damage (%)	Nil	nil

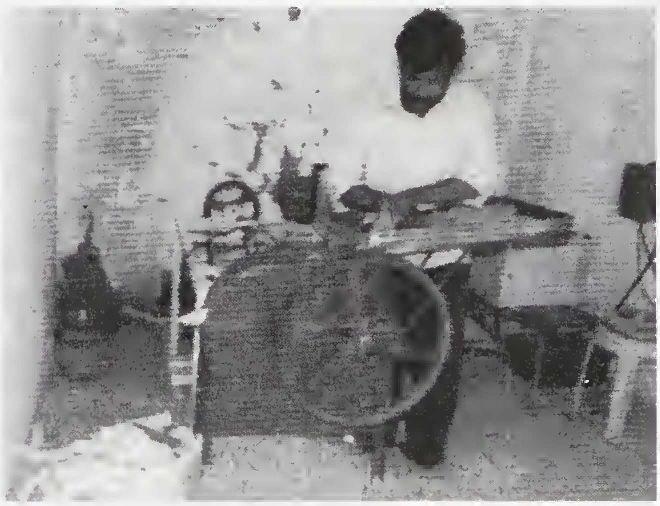


Fig. 18.4. Manually operated rotary maize sheller evaluated.

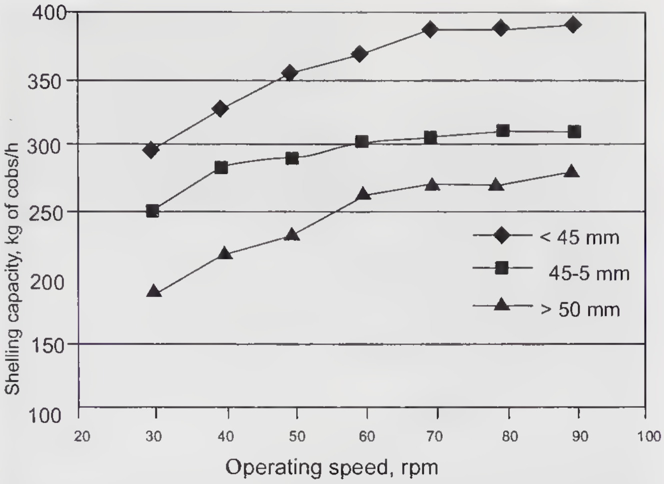


Fig.18.5. Variation in shelling capacity with operating speed for different size of maize cobs with manual rotary maize sheller.

of agricultural workers of Madhya Pradesh to harness the pedal power of the workers. The developed dynapod was tested with the rotary operated manual maize sheller. The unit is shown in Fig.18.4. The trials showed that the shelling capacity with dynapod increased by 59 % over the method of hand cranking. The physiological load on the worker was also less (Fig. 18.5).

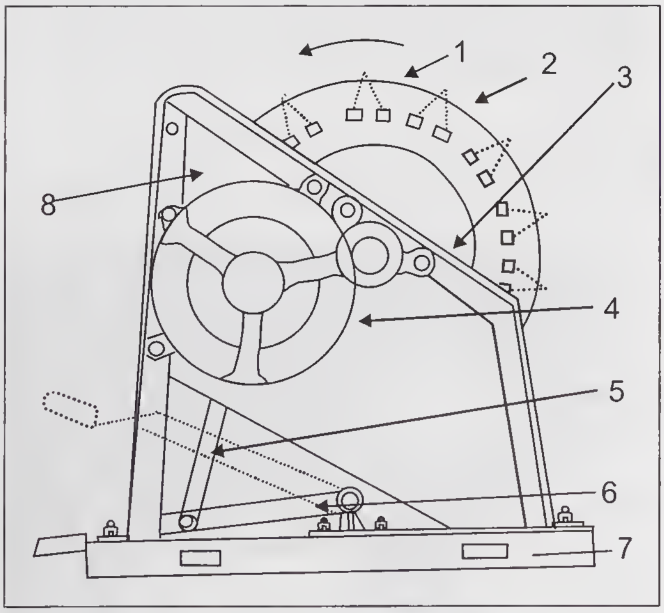


Fig.18.6. Pedal operated paddy thresher. 1, Wire loop tooth; 2, Drum; 3, Frame; 4, Gear Drive cover; 5, connecting lever; 6, Pedal; 7, Base frame; and 8. Side sheet.

Pedal operated paddy thresher

It is widely used machine by the farmers in rice growing regions of India and many Asian countries. The manually operated machine has many good features to thresh the paddy crops. It is sturdy and has only few moving parts, has balanced gear ratio, uses a easy pedal operated rocker assembly and can be repaired at village level. The machine was marketed from 1958-60 and has been exported to many Asian countries. The study was taken up to improve the design for safety and convenience of workers using it and its effect on the workers operating conditions. Briefly it may be stated that the ergonomic study was taken up to improve the design and solve problems encountered during the operation of the thresher for the ease and comfort in the operation and also to make it safe and free from accidents.

The modifications proposed on the thresher are reported as follows:

- *Safety:* Avoid injury to the operator during operation to hands and arm during operation.
- *Ergonomics:* Reduction in drudgery and postural strain caused by pedaling and holding of the crop bundles during threshing. Machine dimensions should suit the different size of workers.
- *Hygiene:* Straw and dust is blown in the air and enter the respiratory system of the farmer causing respiratory diseases.
- *Portability and Transportability:* Machine should be easy to transport on farm roads and on the threshing floor.
- *Storage:* The machine is used only 15-20 days during the threshing season and, therefore, it should be easy to store.
- *Grain separation:* There is no provision for cleaning of the grain hence worker has to perform winnowing in the natural wind or artificially created air flow.

The above points if successfully incorporated in a new design, the paddy thresher will be very useful from the operator's

point of view as it involves improving the work environment and ease in the operation. Based on the changes desired in the design an improved design of pedal operated thresher was developed. The design incorporated the features such as (i) prevention of injury to hand during feeding, (ii) improvement in the work area environments by covering the rotating drum with cover to prevent dusty atmosphere, (iii) providing a hand brake to stop the drum in case of accidents, (iv) eliminating hand injury by providing hand-warning signal, (v) Providing the vibratory sieve for grain separation, (vi) Providing wheels and handle and to move it as wheel barrow and is made to be lifted off the ground by two workers, and (vii) adding an adjustable platform for the operator to feed the crop and keeping pedaling height at 120 mm from ground level. The pedal board is always horizontal with the help of hinge provided at the centre and connected to gear assembly. The modified design is shown in Fig. 18.6.

Thus the conceptualized design of paddy thresher based on ergonomic considerations is reported in Fig.18.6. to Fig.18.8. However, the data about its acceptance by the farmers in modified form is still awaited.

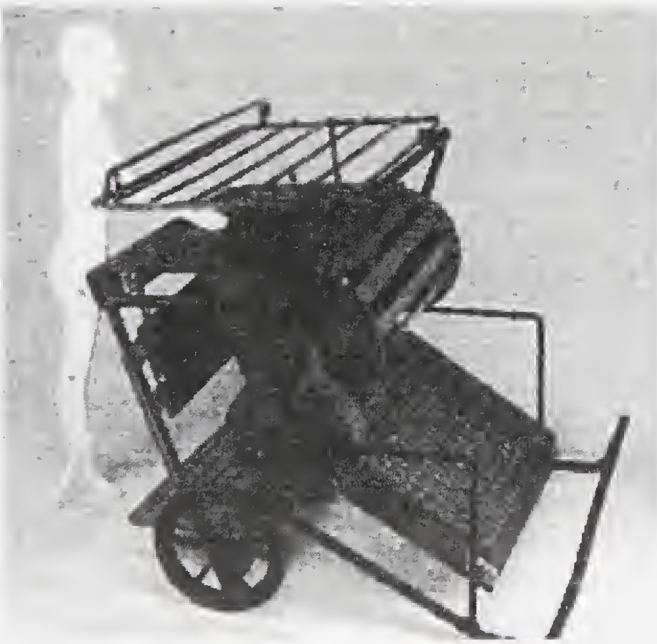


Fig.18.7. Conceptualized modified design of pedal operated paddy thresher with cleaning screen (*Source:* Mantri and Ray 2007).

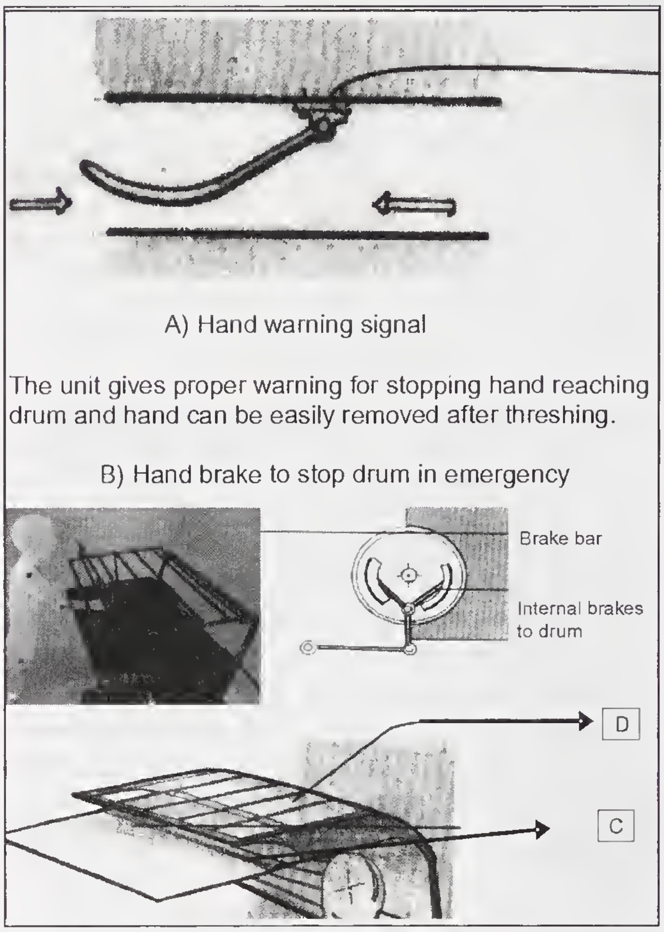


Fig.18.8 (A-C). Safety features proposed on the conceptualized design. (*Source:* Mantry and Ray) A) Safety warning device for manual feeding. B) Installation of hand brake to stop rotating drum. C) Platform for hand support. D) Cover for the drum

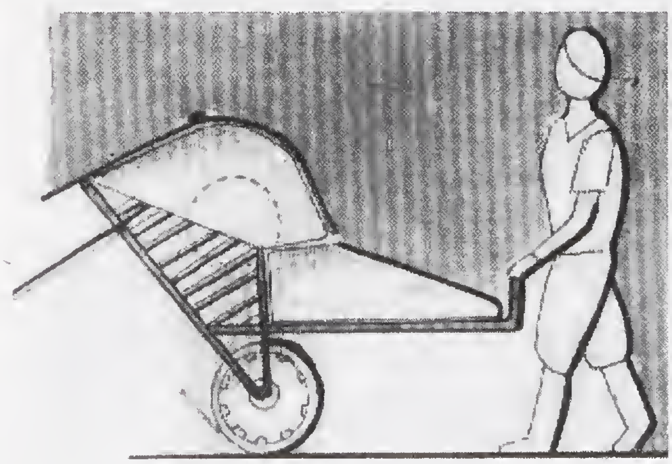


Fig.18.9. Transporting pedal thresher on wheels as a barrow.

Fig.18.10. Modified pedal operated rice thresher for women developed at Orissa University of Agriculture and Technology, Bhubaneshwar (OUAT).

Evaluation of pedal thresher for women workers (Fig. 18.10)

Paddy pedal operated thresher was modified by providing the front cover sheet and setting the height of operating pedal and feeding inlet according to farm workers.

The machine was ergonomically evaluated by the farmwomen workers for use. The group of 12 farmwomen was used in the trials to determine its performance. The details of machine are given in Table18.4.

Female workers operated the unit. It had the grain output of 23.8 kg/h and the crop throughput was 79 kg/h. While working with the thresher the heart rate of the worker was 136-beats/min. This value indicates the operation is heavy work for the female workers and it was recommended to use two workers to operate the unit.

Table 18.4. Performance values of trials conducted on paddy thresher

Particulars	Values
Weight of thresher, kg	41.0
Length of crop stems, mm	725
Pedal strokes/ min.	77
Threshing drum, rpm	278-329
Unthreshed crop %	1.68
Throughput capacity, kg/h	79.0
Paddy grain output, kg/h	23.8
Force required at cylinder rpm of 300, N	162
Heart rate during work, beats/min	136
Work pulse, beats/ min	53

Ergonomic study on CIAE groundnut pod sheller (Fig. 18.11, 18.12)

The manual groundnut sheller developed at CIAE Bhopal was recommended for use and popularization at all India level, therefore the design was considered to take into account the convenience of the operator. Singh (1993) reported the development of improved pod sheller. It was based on the existing design principles of rubbing and squeezing action. To improve the output of unit the concave sieve was replaced by a wire mesh type grate (Fig. 18.11). The unit was modified to adjust the concave clearance easily. The instrumentation was used to measure the force required to break the pods. The physiological effort put in by the operator during operation was measured in terms of increase in heart beat rate and oxygen consumption.

The effort required at the handle grip for breaking the pods was measured by the strain gauge dynamometer and the values reported are 69 N. This force was within the normal limit for continuous pull and push action.

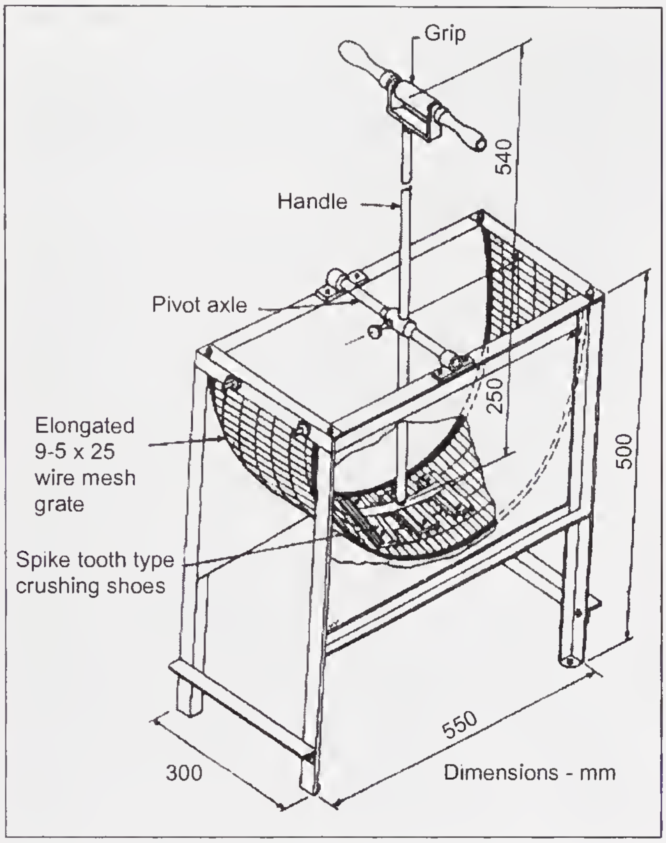


Fig.18.11. Manual decorticator with wire-mesh concave.

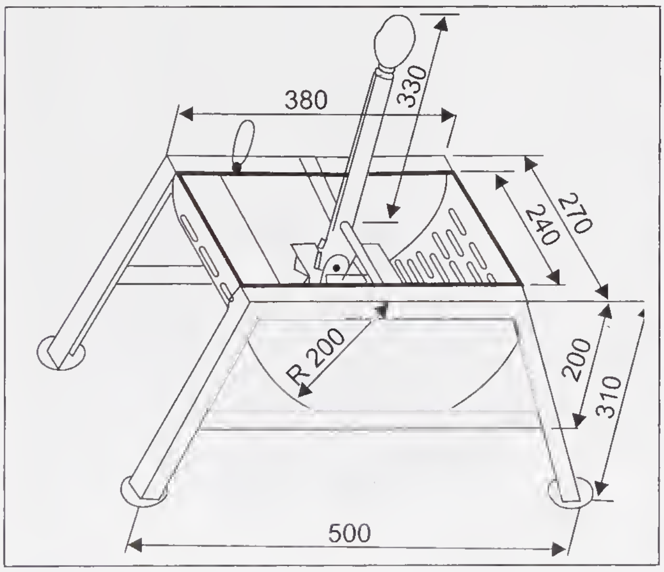
The average heart beat rate of the operator during 30 min test duration was 107.2 beats/min, which was also within the safe limits. The average oxygen consumption of the operator was 0.656 l/min. The physiological data indicated that operator was not physically over loaded to get fatigued during the 30 min test period of operation on the decorticator.

It was concluded that the design is safe for the farm workers and the operation of decorticator can be rated as the safe physiological load.

Female workers operate the groundnut decorticator at home. The oscillating shoe type design is to operate it in standing mode. However, women worker prefers to have unit to be operated in sitting posture and of smaller size to suit her physiologically. Hence modifications were carried out and a suitable model was developed for the female workers, and it was acceptable to them.

Evaluation of CRRI manual paddy winnower (Fig. 18.13)

Ergonomic evaluation of CRRI rice winnower was carried out and the performance is given in Table18.6. The output of winnower was 242 kg/h of clean grain. The average working heart rate of farmwomen worker was 112 beats/ min. The work pulse value was 31 beats/min. This value is within acceptable limit for day long work with standard rest and work cycle. Two workers were used for its operation. One worker was to operate the machine and the other for feeding the material



(A)

(B)

Fig.18.12 (A-B). Groundnut decorticator for operation in sitting mode to suit female workers.

Table 18.5 Ergonomically evaluation data of CRRI hand operated winnower with women workers

Particulars	Values
Weight of machine, kg	36
Handle height from ground level, mm	570
Grain moisture content, % dry basis	18.0
Straw percentage in paddy	2.2
Chaff in paddy grain	11.4
Percent blown grain	1.35
Crank rotation, rpm	65
Blower rpm.	326
Air speed at outlet for chaff, m/s	3.2
Grain output, kg/h	242
Torque at 65 rpm, Nm	5.3
Working heart rate beats/min	112
Work pulse, beats/min	31

Fig.18.13. Women workers operating CRRI paddy winnower.

and collection of grain. It was recommended to provide hooks for hanging of bag to collect the clean grain and perforated sheet cover be provided at the blower inlet to prevent suction of loose clothes of the worker.

Normally the farmers use natural wind for winnowing of paddy. The crop is lifted up and dropped from a height where the light straw and chaff get separated by the air. The winnower is a simple machine, which can speed up the operation of cleaning. It also eliminates human drudgery.

Thus in design of shelling and threshing tools and machines as discussed above it is important to take into account the comfort of the operator during their operation. The long hours of operations should take into account the energy consumption levels, heart beat rates and the posture in which he feels comfortable. In no case the operator be subjected to adverse operating and postural conditions, which affect his health or harms the body parts. This will help in improving the health of farm workers. Even the existing machines used on farms need lot of design improvements from these aspects.

Thus in this chapter different examples have been cited where the knowledge of ergonomics has been utilized in improving the designs of farm thresher and sheller for safety, reduction in efforts and change of posture for operational convenience.

In case of threshers, the major considerations still needs attention of design engineers are the control of noise, vibrations, dusty environments, climatic control for the operator, safety considerations such as instantaneous stoppage of thresher, and ease of making adjustments for proper operation and frequent training of operators which would lead to safe use of equipment while threshing of crops.

The last but not the least important points, which should be given due consideration, are the psychological factors. These factors depend on the dangerous attitudes of the operators, and these are:

- He is brave to take the risks,
- The accidents always happen to other people,
- The job must be hurried to finish in time,
- Occasions when fatigue lowers his judgment ability, need of adoption of work rest cycle, and
- An occasion when second person or helper is needed to ensure safety, but is

considered unavailable without putting in an extra effort. (Especially when thresher is to be set for another crop or for crop material requiring adjustments or due to electric fault).

In the end it is suggested that machines should be fitted with intelligent warning systems to guide the operator not to make the most common mistakes generally made by them to involve in accidents or create situations for them. Designers should aim for making intelligent machine for the safety of the worker.

❑

19 Noise, Vibration, and Dust Control

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The agricultural machines are being increasingly used in India and other asian countries to mechanize the agriculture. Tractors are being widely used on farms as major source of motive and stationary power. Besides that the farmers use the electric motor operated machines such as pumps, threshers, shellers and decorticators. With increasing use of farm machines, safe and comfortable working environments for the operators and others is an essential requirement. There are many occupational hazards with the use of power operated agricultural machines. These include deafness due to high level of noise, the disorder of spinal column, wrists and stomach damage caused due to high level of vibrations. The noise and vibration cause many ailments, which lower the work output and quality and causes misery to the operators. Dusty environments choke the breathing system of workers when exposed for the long durations during various farm activities.

Noise

Farm workers experience the exposure to high source of noise while operating farm equipment. The workers are exposed to noise for the prolonged period when operating tractors, tractor operated machines, combine harvesters, threshers, powered machines and power tillers. Invariably, they are exposed to the high noise levels of threshers, shellers and cleaners for at least 30 days in a season. The noise is the sound that annoys operators. The level of annoyance depends on the quality of sound and our attitude towards it. The human ear responds to two different characteristic of noise, loudness and frequency. The normal range of hearing for healthy worker extends from 20 to 20,000 Hz.

The sound pressure level (SPL) is expressed as sound pressure level with reference to 'reference sound pressure'. It is expressed in dB.

$$SPL = 10 \log (P/P_o)^2$$
$$= 20 \log (P/P_o)$$

Where,

P, r.m.s sound pressure, micro-bars; P_o, reference pressure = 0.0002 micro-bars = 20μP_a where, P_a, atmospheric pressure.

The dB scale is logarithmic and it compares a range of a million into a range of 120 dB. It gives a much better approximation to the human perception of relative loudness than the Pascal scale. The ear reacts to a logarithmic change in level of sound. The audible sound pressure level ranges from the threshold of hearing at 0.0 dB to the threshold of pain in the ears, which is usually more than 130 dB.

An increase of 6 dB represents doubling of sound pressure. An increase of 10 dB is required before the sound subjectively appears to be twice as loud. The small change one can hear is about 3 dB. The human ear is most sensitive to sound between 2 kHz to 5 kHz and less sensitive at higher or lower frequencies.

Effect of noise: Noise induced hearing loss does not usually occur in a rapid traumatic manner. Infact the problem may be acute but the loss occurs imperceptibly, slowly and without pain. Loud noises produce a temporary threshold shift and ringing in the ears and may ultimately lead to permanent hearing loss. Depending on the noise intensity and length of daily or weekly exposure, it may take several years for hearing loss to occur. The losses are usually characterized by a decrease in hearing ability acuity at 4000Hz followed by a spread of conversational (lower) frequencies. Thus the losses in conversational frequencies seriously affect one's ability to communicate. As per the IS 12207 (1997) the maximum ambient noise emitted by machines at operators ear level should not exceed 90 dB (A) for eight-hour durations (Table 19.1). It is reported that 40 hours of exposure will result in hearing loss. The letter 'A' refers to frequency weighing scale, which is shaped approximately like human hearing acuity. This level is given by Federal Walsh Healy act as the maximum allowable 8 h/day exposure unless the ear muffs or plugs are worn by the employee.

When operators are exposed to high sound levels the personal protective equipment is to be provided and used to reduce the sound level. If the variation in noise level involves maximum interval of one second or less, it is to be considered continuous.

Table 19.1 Permissible noise exposure limits for the workers

Duration per day (hours)	Sound level dBA
8.0	90
6.0	92
4.0	95
3.0	97
2.0	100
1.5	102
1.0	105
0.5	110
0.25	115

Noise measurement: The measurement of noise is described in the IS 12180 (Part 1 and 2), 2000; ISO 5131, 1996 and ISO 7216, 1992 for agricultural tractors and self propelled machinery. The standards for threshers are to be prepared. However, for measurement of noise level, the help from available standards can be taken. The values of noise are to be measured as A-weighted sound pressure levels expressed in decibels. The wind velocity at microphone should not exceed 5m/sec (18 kmph). The background noise level shall be at least 10 dB below measured level during tests. The test area be flat and open space, there should not be any obstacle likely to reflect the sound such as building or solid fence etc.

In tractor the position of measurement of noise at bystander position is defined clearly. The measurement is made at different speeds of tractor from 4 to 17 kmph with throttle fully open and at maximum drawbar pull attainable at 15% slip. However, in thresher and other farm machines, the noise level is to be measured close to machines or the operator's level as practiced in, factories or workshops.

The noise levels for the thresher are to be measured in the field or on the threshing floor of the farm. The machine is usually placed on level ground. The thresher is operated at the rated speed and also 15% more speed and 15% less speed than the speed at which maximum output is achieved from the thresher. The crop is fed into the thresher at 75% of maximum feed rate. The positions of the microphone for measuring noise levels are set at the same distance as the operators from the machines in workshop or factories. In thresher the readings are to be taken in stationary position. The suggested positions would be (i) close to thresher as in case of operator feeding the crop; (ii) at least 3.0 m away from machine as in case of workers stacking the crop material on threshing floor; and (iii) 7.50 m away from machine for workers working on threshing floor.

It has been reported that the noise level in power operated threshers are above 95 dBA close to the machine. This is because of aspiratory blower and other moving components, therefore suitable precautions are advisable for the operators of threshers. It is advisable to arrange work schedules such that the farm workers do not exceed the permissible exposure limit to the high noise source.

The noise levels are also high as reported in cotton ginneries. Arude and Paralikar (2004) reported that the noise pollution in cotton gins have never received attention in India. The noise levels in places where double roller gins are operated were recorded to be varying from 87.0 to 97.7 dBA under no load and load conditions. The gin house is reported to be the noisiest place with average noise level of 96.0 dBA. Exposure to such noise may adversely affect the overall efficiency, safety and hearing ability of the gin workers.

Measurement of sound levels: The noise levels can be measured using a portable sound level meter. This meter provides weighing networks for various sensitivity to sound of different frequencies. To simulate the characteristic of sensitivity of the human ear, these characteristics are known as A, B, C scale operating conditions which are selected on the instrument. Least sensitivity is provided at frequencies in the A- scale and highest in C-scale. Therefore, mostly A scale is used to measure the frequencies that human ear can detect. The sound level meter is a portable battery operated and digital display type instrument with measurement range of 20- 140 dB with accuracy of 0.5.

Therefore, till the better and quieter designed machines are introduced, it is essential to protect the operators of agricultural machines from high noise levels. This is achieved by (i) Make sure that the machine parts are well lubricated and the worn out parts are replaced to cut down on noise levels; (ii) The power operated machines be fitted with high quality mufflers; and (iii) The basic designs should incorporate noise reducing measures.

Problem of vibrations

The threshers have been developed indigenously over the years to thresh the different crops. The functional designs of the threshers marketed in the country give very satisfactory performance. But to make its operation safe and comfortable to the operator, great attention is to be paid by designers. To improve their dynamic performance for smooth functioning and prolonged life, a project was carried out with the financial support of Indian Council of Agricultural Research (ICAR), New Delhi at Punjab Agricultural University (PAU), Ludhiana to develop simple methods and techniques for balancing and control of vibrations on the threshers manufactured by small-scale industries during 1982. The spike tooth type threshers are manufactured by the small scale fabricators in very large scale in Punjab state.

The vibration control for the spike tooth type threshers was considered for

improvements and their control because on thresher there are imbalanced rotating masses. Normally on the spike tooth type thresher, there are peg type drum, an aspiratory blower, flywheel and drive pulley and all these parts are mounted on the single shaft that rests on two ball bearings. Such a rotor has to be balanced dynamically to achieve their imbalance to acceptable limits. The manufacturers of wheat thresher normally balance it statically. It is because of single long shaft with multi-mass rotors, therefore, difficult to balance the rotor statically. The torsional vibrations of such multi-mass thresher rotor were studied by Rao *et al.* (1985). The critical speed of these shafts or rotors is generally quite above their operating speed. A rotor is said to be rigid if its operating speed is far below the critical speed which corresponds to the first natural mode of shaft vibrating in flexure. The speed of these rotors is in the range of 550 to 850 rpm. The dynamic balance of motorized thresher is possible with the use of balancing machine. The other source of vibrations is the unbalanced reciprocating sieves or due to operation of cleaning unit. An experimental test rig was developed at PAU to conduct laboratory balancing of thresher rotor dynamically to study the dynamic imbalance.

Measurement of vibrations

Measurement of vibrations becomes necessary for agricultural machines as they are not designed to reduce the level of vibrations because they are required to be made at lower cost. However, there is great awareness towards the comfort of operators; therefore it is essential to determine the natural frequencies, model shapes and damping requirements of threshing and shelling equipments. The theoretical computed vibrations may be different from the actual values due to various assumptions made. Periodic measurement of vibration characteristics becomes essential to ensure the safety during operation. There are two types of vibrations (i) human vibration (ii) machine vibrations. Human vibration is defined as the vibrations experienced by human body as a result of direct contact with vibrating machine or surfaces. In tractor the whole body of the operator is exposed to vibrations of different degrees. Whereas in case of machines like threshers, the vibrations are mostly felt in hands and arms.

The above types of vibrations have a fatiguing effect on the workers, and can reduce the working ability and cause health problems. Thus it is essential to measure the frequency, direction and intensity of vibrations produced during the operation of the machine. The discomfort due to vibrations is experienced if the level of vibrations exceeds a certain limit. Regular exposure to hand and arm vibrations over a number of years may result in permanent damage of the joints and muscles of wrist and elbow. The measurement of vibrations of a vibrating machine involves the pick up transducer which converts the vibrations into electric signal. The transducer changes the mechanical quantities such as displacement, velocity and acceleration and these are changed into electric quantities such as voltage, current etc. Electro dynamic pick up, electromagnetic pick up, piezo electric pick up, inductive displacement pick up, LVDT pick up or capacitive pick ups are the type of transducers used to pick up signals. Since the output of signal of transducer is very small, a signal conversion instrument is used to amplify the signal. Thus the amplified signal is used for recording in a computer or can be displayed on a display unit like oscilloscope, milli-voltmeter or on the computer etc. Depending on the quantity measured, the vibration measuring instrument is called vibrometer, a velocity meter, an accelerometer or a frequency meter.

Displacement measurements are useful for studying low frequency vibrations, where the velocity and accelerations are too small for practical purpose. Velocity measurements are useful for intermediate frequencies; here the displacements are very small.

Accelerations are measured when high frequencies vibrations are involved and are of concern.

Vibration pick ups are called seismic instruments. The basic element of vibration measuring instrument is seismic unit (Fig. 19.1-19.3) which is a spring mass – damper system mounted on a vibrating body on which measurements are to be made.

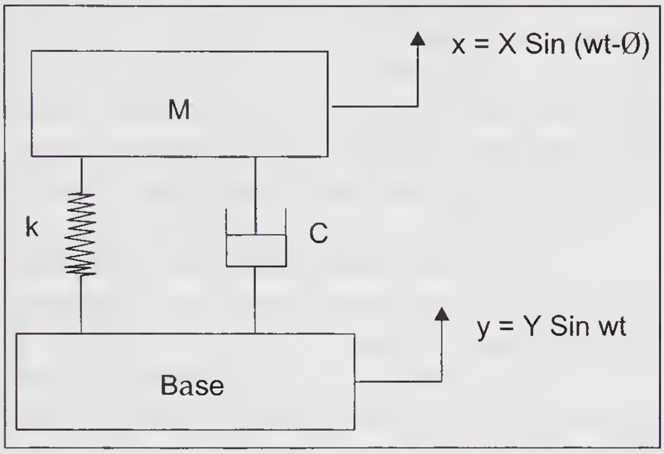

Fig. 19.1. Free body diagram of vibrating machine on the base platform.

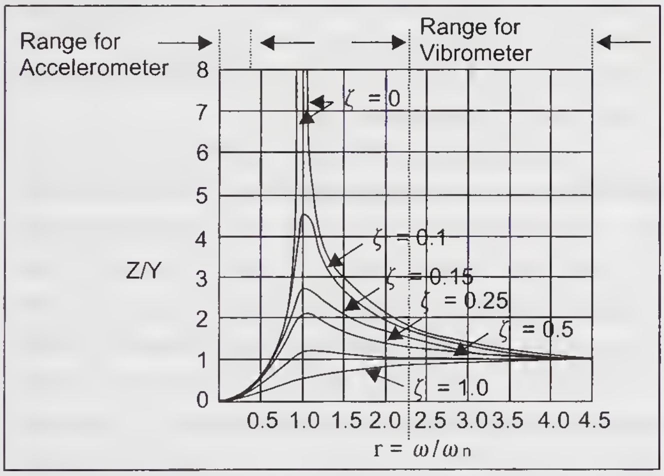

Fig. 19.2. Frequency response curves of vibrating machine.

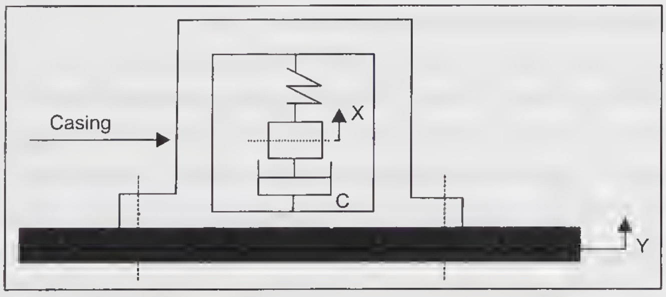

Fig. 19.3. A basic seismic unit represented by free body diagram of mass, spring and dashpot mounted on base.

The behaviour of seismic mass or unit is given by equation:

$$m\ddot{X} = -c(\dot{X} - \dot{Y}) - k(X - Yy)$$

$$Z = X - Y \quad \text{is relative displacement.}$$

$$m\ddot{Z}\ c\dot{Z} + kZ = m\ \omega^2 Y \sin \omega t$$

From these equations the parameters that influence Z/Y and φ are i) frequency ratio

$r = \dfrac{\omega}{\omega n}$ and (ii) damping factor Σ as shown in Fig.19.6

The relative displacement Z may represent displacement or acceleration depending upon (ωn) of seismic unit and frequency of vibrating body, ω.

The vibrometer is an instrument when the natural frequency of device is high compared to that of vibration to be measured. Fig. 19.2 shows the range of frequencies corresponding to which a seismic pick up acts as a vibrometer or an accelerometer. The type of pick up is determined by the useful range of frequencies with respect to natural frequency (ωn) of the pick up device. The relative displacement z, may represent the displacement or acceleration depending upon (ωn) of the pick up and the frequency of the vibrating body. Therefore, vibrometer is used to pick up with low natural frequency ω >> >> ωn and r >>>> 1 is very large

Z/Y =1, when r >3 and therefore Z=Y. This means relative displacement of pick up unit is equal to the base of machine where it is fixed.

Hence the seismic mass remains stationery and the relative displacement between the casing and the mass is the true displacement casing, like wise the relative velocity between mass and casing is the true velocity. The seismic motion Z is converted into electric voltage. Thus the output of instrument is proportional to the velocity of the vibrating body. The instrument is called vibrometer or velometer. The range of frequencies for the

instrument may be in the range of 1 to 5 Hz and the useful range from

10Hz to 2000Hz with sensitivity in the range of 20.0 milli.volts/cm. Thus the displacement and acceleration are measured from the velocity type transducer by means of integrating or differentiating circuits provide in the signal conditioning unit

Accelerometer: It is a pick up unit with high natural frequency. When the frequency of pick up is high as compared to vibrations to be measured the instrument indicates acceleration.

$\omega <<<< \omega n$, and $r <<<< 1$

Thus $Z \longrightarrow (\omega/\omega n)^2 . Y$

or $Z \propto \omega^2 . Y$

This implies that Z is proportional to the acceleration of the vibrating body.

Thus ωn should be very large, the mass be small and spring stiffness be high. Thus instrument or pick up is small in size and compact and hence preferred in the measurement of vibrations. The accelerations measured can be integrated once or twice to obtain the velocity and displacement of the system. Thus the difference in two pickups is that of natural frequency. Mostly accelerometers are used because of their small size.

Setup for study of vibrations on thresher

The balancing machines are very costly and beyond the reach of small-scale fabricators of threshers. Thus it was necessary to determine the extent of imbalance and balance the rotating and reciprocating masses without the use of balancing machine. The aim was to study the dynamic response of the rotor in place without disturbing the actual positions of the bearings. Fig. 19.4 shows the front side view of the experimental set up used for conducting the dynamic performance studies on spike tooth type thresher under laboratory conditions. A rigid adjustable steel frame supported the variable speed D.C. motor used for running the thresher through a flexible coupling. The upper cover and transport wheels of the thresher were removed. Temporary legs were fixed to the frame directly to heavy concrete floor with the help of grouted foundation bolts.

The flywheel and a specially made circular ring mounted on the shaft between the driving pulley and aspiratory blower were used as two planes for mounting the balancing weights. There was provision of mounting clamps to hold the trial masses, which can slide, along the periphery of the flywheel and circular ring. The angular position of the trial masses can be read off the circular scale in degrees.

The vibration levels were measured at the ends of the horizontal members supporting the bearings of the rotor shaft shown as station-1 and station-2, on the member directly supporting the rotor bearing near the flywheel station-3 and on the vertical member where the sieve driving mechanism is attached (Station-5) and its top in the vertical direction Station-5. Denmark make, Bruel and Kjaer vibration and noise measurement and analysis equipment were used.

The dynamic balance of the multi mass thresher rotor was carried out in the laboratory by running the rotor at a constant speed and without feeding the crop. The rotor was considered to be rigid one, as it operated at the speed of 820 rpm, which is sufficiently below its critical speed of 1,685 rpm (Rao *et al.*, 1985). A rigid rotor need not be balanced by running it at its operating speed. The thresher speed was varied gradually from 0 to 1,200 rpm to find the speed at which the thresher frame had large resonant response.

For the end conditions provided by its being fixed to the floor, the thresher frame was found to resonate at the rotor speed of 620 rpm and large amplitude in the lateral direction. To avoid resonance, speed of 600 rpm was selected for the experimental investigation. A trial weight of 165 g (1.62N) was used to locate the angular position of the imbalance on the flywheel end. The trial weight was made to

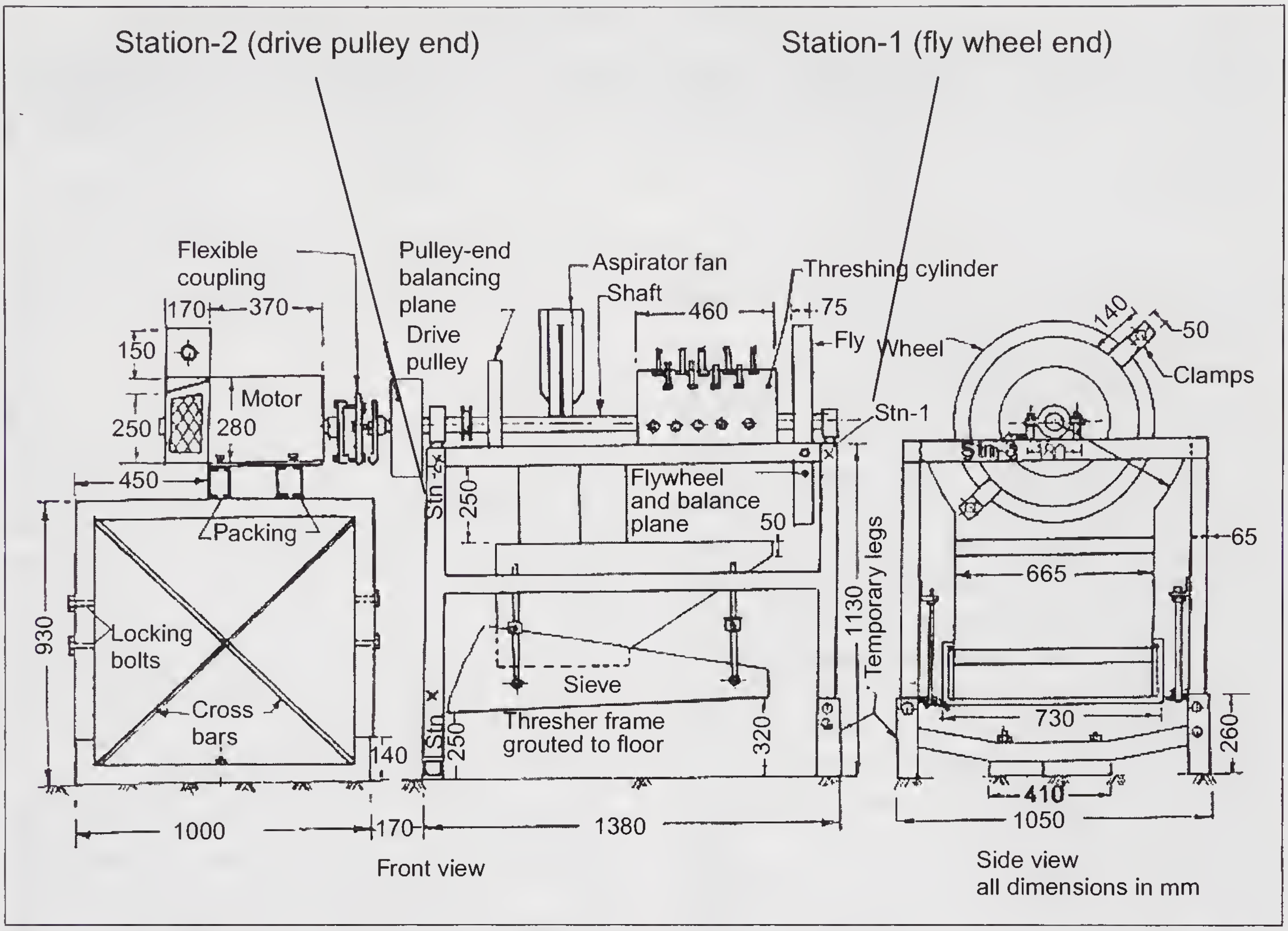

Fig. 19.4. Set up for dynamic balancing of multi-mass rotor of spike tooth type thresher. (*Source:* Bansal *et al.*, 1998)

slide along the flywheel rim through 10-degree interval and the response at the flywheel end was recorded.

The angular position for the minimum response was 315 degrees. At this angular position the weight that gave the least response was also found. With this balance weight in position the system was balanced at the pulley end (station-2) by following the same procedure and running the rotor at the same speed. The above procedure of alternatively balancing the flywheel end and then the pulley end had to be repeated only a couple of times until the system was balanced and no change in location or amount of balance weight was necessary. This showed fast convergence. Table 19.2 presents the total imbalance and amount of imbalance removed.

Thus total imbalance was 43300 g-mm (425 N-mm). The weight of thresher rotor weighs 139.15kg (1365 N), the imbalance removed was 43300/139.15 = 311.5 g-mm/kg body weight of the rotor.

Minimization of structural response procedure was found to converge rapidly. The rotor had a large unbalance of 387.65 g-mm/kg body weight that was brought down to 76.48, a value well below the limit of 160 g-mm/kg body weight as per ISO standards. The resonant response of the balanced thresher rotor drum was found to be reduced by 78.8%. It was recommended that the thresher rotor can be dynamically balanced after mounting the major components on the shaft

Table 19.2 Balancing weight and their location on the thresher rotor (*Source:* Bansal *et al.* 1998).

Balancing plane/end	Angular position, deg	Radial position, mm	Balance wt. g (N)	Unbalance g-mm (N-mm)
Flywheel	315	395	20(0.2)	7,900 (77.5)
Pulley end	300	295	120 (1.18)	35,400 (347.3)
				43,300 (total)

and fixing of the bearings brackets in proper positions.

Balancing of reciprocating masses: The cleaning shoe weighing 29.16 kg (286 N) was given a reciprocating motion through a driving mechanism with eccentricity r = 7.5 mm and connecting rod length of 120 mm. For such high value of the ratio l/r =16, higher harmonics of periodic excitation force arising from the reciprocating motion of the sieve unit can be considered negligible. The oscillatory motion of sieves can be considered to be sinusoidal. The driving pulley that was used to mount the counter balance weight was statically balanced by adding a weight of 210 g at a radius of 85 mm at appropriate angular position. The weights required for balancing different percentage of total reciprocating mass were mounted on the driving pulley and 60% counter balancing was optimum for least vibration response.

The field conditions under which the thresher operates are different from those in the laboratory. In the field the thresher rotor operates at 820 rpm while actually threshing the crop. It rests on the transport wheels, which get partly sunk in the soil on the farm. The effect of balancing on the vibration control was further studied under field conditions. The response of station-1 and station-2 was recorded over a range of frequencies with the thresher balanced and imbalanced while operated under threshing load and no load conditions.

Experimental results: The results of experimental studies are reported in Fig.19.5 and 19.6. The Fig.19.5 gives the responses in terms of accelerations in the horizontal and vertical direction as measured at station –5 at

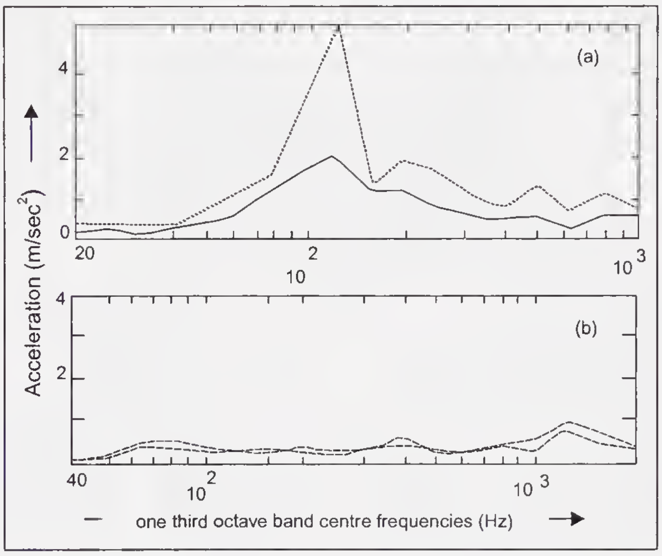

Fig. 19.5. Effect of counter balancing of the reciprocating masses in horizontal (a) and vertical direction (b) - - - - -, before balancing and -------, after 60% balancing. (*Source:* Bansal *et al.* 1998)

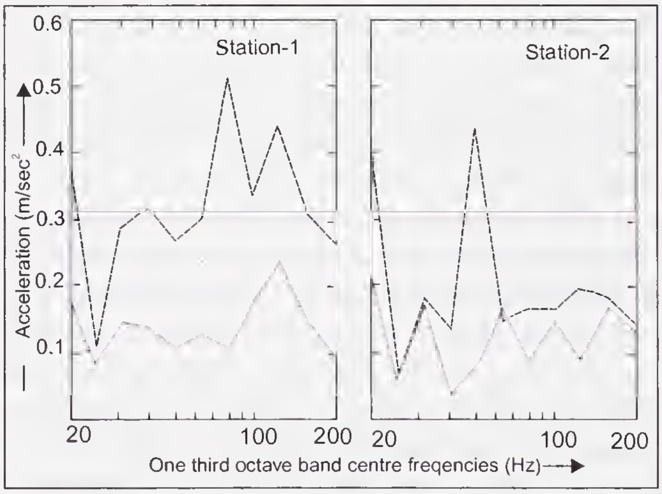

Fig. 19.6. Effect of dynamic balancing of thresher rotor on vibration levels at Station-1 and Station-2. (*Source:* Bansal *et al.* 1998). (-------before and ---------, after balancing of thresher).

different 1/3 octave band centre frequencies, before and after balancing the reciprocating

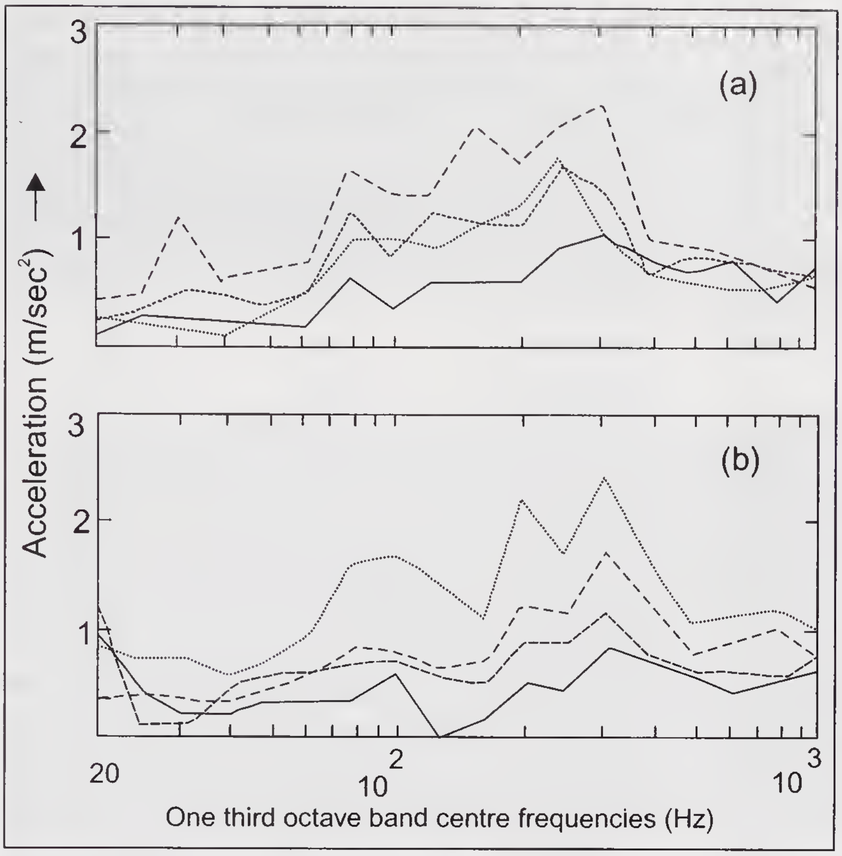

Fig. 19.7. Effect of balancing studied under field conditions at station-1,(a) and station-2,(b) (*Source:* Bansal, *et al.* 1998) (......., before balancing without threshing, - - - - - -, before balancing while threshing,. - . - . - . While threshing before balancing and while threshing after balancing).

reduced by 80.3%.

Combined effect of balancing of reciprocating and rotating masses: The counter balancing of 60% of the reciprocating mass of the sieve assembly was reported to give the best results. By stiffening of the thresher frame member the major response peaks reduced by 63 and 89.7% at the flywheel and the pulley end respectively. The balancing of rotating and reciprocating masses also reduced the noise level by 2 dB(A).

The simple method, which is similar to the method of sequential minimization of structural response, was very effective for in place dynamic balancing of rigid multi-mass thresher rotor. Counter balancing the reciprocating masses to the extent of 60% was the most effective in reducing the vibrations. Balancing of both reciprocating and rotating masses brought down the vibration by 75 to 90% under laboratory conditions and by 60% under field conditions. It resulted in smooth functioning of the thresher. In the end it was recommended that the manufacturers should balance the rotating masses and the reciprocating masses for the prolonged life of machine.

masses. The peak value of acceleration level was lowered from 4.9 to 2m/sec^2 which were equal to reduction of 59.2%.

The vibration level at the flywheel end and pulley end were also measured and are shown in Fig.19.7. The balancing of multi-mass thresher rotor showed the reduction of 80.7% to 78.4% of the highest response peak at the pulley and flywheel ends. Considering the peak response values to be proportional to the imbalance, the residual imbalance was determined. Thus the total residual imbalance value calculated was 76.48 g-mm/kg of body weight, which was considerably lower as compared to 160 g-mm/kg value permissible for the agricultural machinery as per ISO (1940-1973(E)). It was concluded that the imbalance for the spike tooth thresher was

Air borne dust and dust control

The operation of threshers, cleaners, shellers including machines used for removing of chaff, straw and other particles from grains and other crops produce the dusty environments under which the operators have to work. In cotton or other fibre crops, the workers are exposed to noise, vibrations and air suspended dust particulates. In jute and allied fibre crops which are processed by retting have to work for long hours in dirty water conditions. All these situations are

a nuisance as well as potential respiratory problems, hearing loss, and skin diseases hazard. Though the workers take simple precautions of covering their faces with the piece of cotton cloth and many times the direction of straw thrower of thresher is set in the direction of wind so that the dust particles fly away from the operators. However, there is still a plenty of dust and noisy surroundings near the area of threshing operation.

The dust problem in cotton ginning is very severe as the workers are supposed to work for the continuous period of months in the ginning mills. Therefore working on the conventional gins where operators are employed in the cotton processing industry, they are exposed to respiratory dust. This often results in the health problems particularly the fever with unique symptoms. The fever syndrome is popularly known as Byssinosis. Inhaled dust causes cough, cold, breathing difficulty and also lead to lung disorders. The common complaint is the difficulty in breathing and tightness across chest.

The earlier breathing difficulties may be reversible however constant exposure to same conditions may cause permanent disability. The particulate matter (PM) is the form of pollution composed of very small particles of dust. Smoke, soot and particles are of mineral origin or bio-products. The Environmental Protection Agency (EPA) has identified two types of PM with which the health risk is associated. These are PM10 and PM2.5. The PM 10 refers to particulate of size 10 microns and PM 2.5 refers to particulate of 2.5 microns. The PM of 2.5 microns are most dangerous as they enter into the lungs and remain lodged there thus cause great damage to the operators. The dust concentration levels at different workstations in the conventional ginnery were recorded by Arude *et al.* (2004) and reported in Table 19.3.

Table 19.3 Airbourne dust concentration of 2.5 PM and 10 PM at different work stations in conventional ginnery in Maharashtra. (*Source:* Arude and Paralikar 2004)

Work station	Air-borne dust concentration, Time Weighted Average (mg/m³)	
	PM 2.5	PM10
Gin house	0.23	0.32
Press house	2.30	3.75
Lint opener	1.92	2.14
Cotton heap	0.002	0.004

The permissible limit of dust reported was 65 and 50 microgram/m³ respectively. This level is reported for the cotton heap work area. The values for the other stations are high. The dust levels in semi automatic and automatic ginneries are also reported to be high. The air dust levels for the places where threshers are operated have to be studied to help farmers in taking precautionary measures till better machines are designed and made available to them for use.

The operators of agricultural machines are likely to be exposed to noise, vibrations and dust particulates while performing the operation like threshing, shelling, decorticating, and extracting of fibres from plant and those working in cotton ginning mills or cotton mills. In all these areas the level of pollution is above the normal permissible limits. It is very essential to design the machines which are safe for the operators. In the mean time personal protective measures should be also taken. Simple precautionary methods/ devices are required to be provided by the owners of the machines to the operators.

❑

20 Installation, Operation and Maintenance of Threshers

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The threshing operation has been mechanized to a greater extent because of the green revolution in many of the developing countries which brought in the increase in crop yield levels and productivity especially in the wheat and rice producing regions. The increased use of machinery by the farmers resulted in a number of accidents especially due to use of threshers resulting in the temporary and permanent disability of workers. The accidents were due to machine, human, crop and other situational factors. The accidents also brought to the attention the need of adoption of safety measures on the part of manufacturers, the users of threshers and the employer of workers. Hence training of owners as well as workers likely to use threshers is greatly emphasized. As the accidents were greatly affecting the farm workers of rice and wheat producing regions suitable measures were taken by the government of India to provide protection to them. This also helped in introduction of standards for the production, sale and use of machines. Thus the three prong approach helped greatly in reducing the rate of accidents in the country.

The threshers manufactured were either tractor or electric motor operated machines hence their use on the farm requires proper installation, their operation on the threshing yard including thorough checking of machine before its installation. Hence, there is a need to prepare and provide an instructions manual for its proper use, maintenance and care. The manufacturers were encouraged to provide necessary information to the purchasers of threshers by means of instruction manual in local language.

Installation

The prime mover unless directly mounted on the thresher as in case of electric motor operated units should be located such that the machine weight is well balanced and the bruised

straw being blown away from machine does not fall on it. The location of motor is normally mounted on the bracket close to the threshing drum or at the base of frame to provide stability and it is attached to main frame. The motors used are mostly operated by three phase power supply system. Hence, it should be fitted with a matching motor starter without exception. The uneducated farmers are habitual to operate the thresher by connecting it direct on line. This happens to be the major cause of accidents and fire hazards. Therefore, motor on thresher should be operated with starter of proper size with protection against sudden surge in voltage or current. The cable used for connecting the power supply to thresher should also be of proper size. For 3.75kW size motor cable with current carrying capacity of 15/20 amperes rating is used. For high power motor the cable size should also be increased as recommended by qualified electrician holding proper licence. Many times direct on line starters are used by the farmers and they should have proper protection against burn outs. The main switch of the motor should be fixed within easy reach of the operator, to stop the machine easily in emergency.

In tractor operated thresher, it is to be set on the threshing floor of the farm. The power is mostly transmitted by means of long flat belt driven by tractor p.t.o pulley. At present the belt drives have been changed and threshers are operated by the universal joint shaft which connects the machine with tractor and very convenient for operation. The exhaust pipe of tractor should always be vertically upwards. The tractor should be sufficiently away from the heap of crop or '*bhusa*' to avoid fire hazards.

The *bhusa* 'bruised straw' which is mostly thrown out of machine by aspiratory blower is to be collected. Therefore, the unit is operated close to a wall of the threshing floor or straw enclosure for making a heap. During machine operation care should be taken to see that straw is not blown towards residential or office buildings. As *bhusa* particulates causes nuisance to persons living nearby, all precautions be taken to keep the surroundings clean and dust free. Under no circumstances, *bhusa* be allowed to be blown into nearby drinking water well or residence.

Normally the thresher is operated in close place where harvested crop is stacked. At the threshing yard the provision of first aid box and arrangement for extinguishing fire need to be arranged. This should be in form of sand buckets, water buckets, water tank and fire extinguishers. Thus fire can be extinguished as soon as it is noticed. The dry crop catches fire easily when the ambient temperatures are above 42°C, hence smoking while working or resting near the thresher is to be banned. The workers should also be trained to control fire hazards in case such situations arise.

Points to be checked on thresher by buyer

- The purchaser of thresher should check the following points for the safety of the operator as well as smooth functioning of machine as a whole.
- The size/capacity of thresher should be according to the prime mover available with him.
- The direction of rotation is clearly marked on the drum along with the speed at which it is to be operated.
- The operator's manual should be in the local language and understood by him and he understands the meaning of terms used in the document.
- The special tools and accessories have been supplied by the manufacturer for adjustments to be made during operation of machine.
- Safety provisions are provided in the thresher especially the drive belts are covered with safety guards, and there is proper provision for oiling and greasing of moving parts.
- After sale the service facility is available along with free installation or demonstration on the farm.

Operational conditions to be observed

- The thresher should be firmly set on the threshing floor. The wheels should be grounded firmly during operation.
- Machine should be set level in both directions.
- The power drive be aligned and direction of rotation be as per recommendation.
- The belts are properly tightened.
- The bearings and bushes on machine are greased or oiled as per manufacturer's instructions.
- Proper platform be made for the worker near the thresher to facilitate smooth feeding of crop in the machine and preventing the falling down of the operator.
- Before starting the machine operate the machine with hand and check, whether it is moving freely.
- The crop should be feed uniformly and continuously.

Precaution during operation

- Smoking and lighting of fire close to thresher is not allowed.
- The operator should not work on the machine under the influence of liquor or intoxicant etc.
- The worker is given rest after continuously working for 1-2 h on the machine or as required.
- The worker should not stand on the machine to feed the crop. There should be suitable platform for the operator to feed the crop conveniently.
- Stop the machine immediately if an unusual sound is heard.
- Worker should not wear loose clothing when working on the machine.
- Even though safe feeding chutes are provided on the thresher still the operator be advised not to push the crop inside threshing drum with hands.
- The cable or electricity wires should be properly covered and insulated.
- The machine is switched off before making any adjustments.
- The workers should be clearly informed about the proper method of starting and stopping of machine.
- The problems he is to encounter during operation and safety measures to be taken care of.
- No children are allowed while working on the machine to stand by or to help in operation.

Problems and troubles during thresher operation (Table 20.1)

During operation of a thresher many times problems are noticed and these can be related to, (i) the improper setting of thresher, (ii) the crop conditions may be unsuitable for threshing; and (iii) speed and direction of rotation of main thresher shaft may be incorrect. These situations cause problems in smooth functioning of the machine. The main problems can be described as related to machine setting or those related to the grain output and damage of grain or losses caused due to blower, cylinder or the cleaning shoe settings.

Regular care and maintenance

- Keep the machine beyond the reach of children.
- Lubricate parts as per instruction manual.
- Check the tension of drive belts.
- Replace or repair the part damaged due to wear or tear.
- In case of excessive sound or vibration look for the trouble spot and rectify the same before using the machine.
- Don't remove safety covers from drives.

Instructions for off season storage of thresher

1. The machine is run at idle to remove the entire crop or plant material from inside. It should be cleaned thoroughly by air blast or manually.
2. The power unit is removed from the machine for safe storage.

Table 20.1. Most frequent problems faced by the thresher operators, the causes and remedies

Problem	Cause	Remedy
More of broken grain	High speed of cylinder	Check the speed and reduce to recommended level
	Low concave clearance	Increase concave clearance by reducing the length of pegs or as suggested by manufacturer
	Low and high feed rate	Feed crop evenly and freely and do not choke the cylinder
	Crop moisture low	Reduce cylinder speed
		Reduce number of spikes on cylinder
Too much grain going with the straw	High blower speed	Check the blower speed and correct it as recommended
	Improper sieve setting	Increase sieve slope and lower the sieve at lower or outer end
	Sieves clogged	Clean the top and second sieves' holes
Poor cleaning	Low blower speed	Check blower speed.
		Check the tension of the motor blower belt.
	Improper sieve setting	Increase the sieve slope and stroke length or and speed of shaker.
Poor threshing	Low speed of cylinder	Check cylinder speed and tension of motor cylinder drive belt.
	High concave clearance	Reduce the concave clearance
	Improper concave	Fit the concave of proper size
	High crop moisture level	Allow the crop to dry up to desired moisture level. As crop absorbs the morning dew.
Cylinder choking or blockage of drum	High moisture level of crop	Allow crop to dry before start of threshing
	High feed rate or overfeeding of crop	Feed crop uniformly
	Low cylinder speed	Set speed according to crop as recommended. Adjust belt tension
	Improper concave	In grate opening are small, it would choke the unit.
	High concave clearance	Reduce the clearance by increasing length of drum beaters. Lift the concave grate
Blower choking	Low blower speed	Check blower speed and tension of the belt of blower drive
	High feed rate	Reduce the feed rate, or feed the crop evenly in the threshing unit
	Improper flow of straw on top sieve	Increase sieve slope in small steps. Clean the top sieve in case holes are blocked by straw or chaff
Vibration in machine during operation	Improper Installation	Properly install the thresher
	Fasteners and bearings are loose	Tighten the fasteners and tighten bearings
	Worn out components	Repair or replace worn out parts

3. The parts are properly protected against rust. Bearing and moving parts be greased and oiled well.
4. The drive belts are removed for storage.
5. The machine be stored in farm shed or covered properly with tarpaulin or plastic sheet for storage in open.
6. The openings of machine are covered to prevent entry of household vermin's.

It is noted that the operator's manual or thresher installations and maintenance instructions are usually printed in English or Official language of the state, It is the responsibility of manufacturer to provide instructions in the language understood by the farmers where the machines are sold. Further even though the operator normally would show he knows and is aware of the precautions to be taken, still the safety measures to be taken be emphasized during the threshing seasons to the farmers. ❑

21 Standards for Threshers

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The threshing operation was very laborious operation in the past, when human and animal power sources were used. The uses of machines and electric power units have helped farmers to reduce the turnaround time during the crop growing seasons. Thus he is able to grow two crops during the year. The thresher has helped farmers to overcome the labour shortage and also helps in preventing grain damage due to untimely weather conditions. Thus mechanization of threshing operation has played a pivotal role in ushering in an era of green revolution in the country and also brought in the bumper crops at the farmers field levels. The thresher is a machine which is manufactured by small scale fabricators at number of places in the country. Therefore there was need to develop the Standards for the machines, so that the interest of users of machine are protected. Thus farmers are not exploited by the marketing agencies of these machines. Hence the standards were developed to provide detailed specifications of machines along with pictorial details of machine for purchasers and users.

The advantages of standards is to provide the industry enough detailed information to make a product of standard design and meet the minimum level of performance as specified by the institutes on behalf of users of machines.

The standards are made so that the durability of product is established under specified working conditions on the farms. In many cases the manufacturers would give/ specify the output of machines under best working conditions. Thus mislead the buyers of machines. The standards also provide the guidelines and procedures to perform the tests on the machines for the benefit of users to check whether the performance standards are achieved. It also specifies the range of losses to be expected during operation by the farmers.

In short the standards are to provide product of quality to meet the requirements for the most of users and, therefore, beneficial for both the farmers and manufactures.

History of introduction of standards in India

The standards for the agricultural machines were prepared with the cooperation of government organizations, private industry, research institutes, testing stations and people involved in use and production of the products etc. A large number have been prepared and published by the Indian Standard Institution for the benefit of the governmental agencies and agro industries who were responsible for introducing and popularizing, hand tools, animal drawn implements and power operated machines among the farmers. Indian Standard Institute is presently known as Bureau of Indian Standards. It started its role of developing and releasing the standards of various farm equipment from the early sixties. During the last fifty years it has covered a wide range of agricultural machines of different types. Thus it has played a great role in helping popularization of machines among the farmers and helped manufacturers of agro equipment in India.

The first standard released on threshers by Bureau of Indian Standards was for the pedal operated Paddy thresher as IS 3327-1965. The pedal operated threshers were introduced in India during 1956-57 among the farmers. Of course these machines were initially imported from Japan and supplied to different research institutes and other State Government Agencies such as State Agro Industries Corporations. They were involved to evaluate and undertake production, procurement and supply of useful machines including threshers to the farmers.

The next standard on threshers developed was the standard for animal drawn Olpad thresher developed at Allahabad Agricultural Institute, Naini, and Allahabad and used for threshing of wheat crop and making *bhusa*. The machine consisted a number of serrated discs mounted on the frame are pulled over the crop by the animals to break up the crop mass and separate the grain from the ears. This standard was termed as IS 3163-1979. This standard gave the details of machine components, specifying the machine dimensions, arrangement of components, etc. It also described its proper usage. Indian Standard Institute further emphasized the need of providing the finished product and keeping in mind the safety features for the operators.

Power operated threshers

The agricultural mechanization was given push by all concerned agencies after the green revolution. The mechanization of threshing became a necessity for the farmers in the wheat growing regions to reduce the turn around time. The farmers were encouraged to raise two and more than two crops to meet the food requirements of the growing population. It was possible because of the adoption of modern agricultural practices. Thus a large number of small scale industries were established in many industrial areas of the country to fabricate and market the threshers and other farm machines.

The Punjab Agricultural University established the farm machinery testing centre to help the small fabricators to improve their products and to know the performance of their machines. This was necessary as each manufacturer claimed his machine to be the best on the market. A large number of threshers were tested at the centre and the test reports were released for the users.

The Government of India had also established the Tractor testing and training institutes at Budni, in Madhya Pradesh and Hisar in Haryana states for conducting official tests on farm equipments also. However, the Budni station was mostly busy in testing of tractors. But the second Testing station at Hisar was assigned the job of testing the agro equipment to help the local industry and the users of machines. By 2000 two more such institutes have been established in Andhra Pradesh and Asom states to take care of most of the regions.

The first standard test code for stationary threshers for wheat was prepared and introduced in 1975 as IS: 6284-1975. This test code covers the complete information on reporting of complete specifications of machine, definition of terminology used and the test code for testing the machines and reporting the test results for the benefit of users etc.

Need for test procedures for research and development institutes

The ICAR had set up the All India co-ordinated Project on Research and Development, Prototype Production and evaluation of farm Implements and machinery at various centres located at different ICAR research Institutes and State Agricultural Universities with the objective of identifying suitable machines for all the regions of country. Therefore during 1978 the need for farm equipment testing procedures was felt by the coordinating centre at CIAE, Bhopal, so that the test engineers would present the reports during annual workshops on the evaluations of machines in a standard format. Up to this time the reports received were mostly vague and no useful conclusions could be drawn. To do proper field evaluation a team of five staff (laboratory assistance, field worker, machine operator and mechanic) were provided to take the field observations, conduct laboratory tests and do the field trials on the crops or operations. The test duration of at least 2 hours or more was recommended. The ambient conditions, soil, crop and other parameters were to be recorded. The group was also provided with test instruments etc, to record the data during trials etc. All this was necessary to have experimental data from which useful conclusions can be drawn. Thus test procedures for tillage, sowing, intercultural, plant protection, harvesting and threshing equipments were developed and finalized after the group discussions at project level meetings.

Test procedures and standards by RNAM project

These test procedures were found very useful and at later stages these were further improved upon by experts and published by Regional network of Agricultural Machinery to be adopted for the test and evaluation of prototypes supplied by various countries to respective national level Institutes for popularization programs of useful machines. Thus authors emphasize that for field evaluation or evaluation on the farmer's level of machines be conducted in scientific manner and data be properly recorded and analyzed for the useful conclusions. There was tendency on the part of test engineers to conclude without enough test results that the performance of machine was excellent or very good. These types of comments should be avoided. Further field or laboratory testing of machines would require a minimum of at least five technical or skilled workers to get proper observations during evaluation process. This fact is normally ignored at most of the research institutes in many Asian countries. Thus the test procedures were developed and utilized in evaluation of threshers. These were finalized and reported in the *Chapter 17*.

The second machine for which the test code and procedures were developed is the groundnut decorticator. The full details for this machine are provided in the Test Codes prepared by the RNAM-UNDP (ESCAP) and supplied to all the participating countries. This has resulted in popularization of the successful machines for oilseeds production in India.

International Standards

These standards are for the equipment for harvesting and under these the details of functional components such as threshing cylinders are described. Thus these standards describe the dimensions of threshing cylinders, concave grates, concave extensions, cylinder width etc. In cleaning devices the sieve measurements are described. The terminology

used for describing performance of machine is covered with emphasis on the total feed rate and grain loss. The material other than grain feed rate is described. It means the material other than grain passing through the machine per unit time. The MOG feed rate is expressed in terms of Kilograms per second. It is noted that evaluation of combine harvesters is specified for the grain moisture range of 10-20 % and MOG moisture level of 10 to 25%. The ranges of processing losses described are 1% for wheat, 3% for rice, soybean, maize and oilseed rape crops as per the ISO 6689-1981(E).

The farm machines recommended to the farmers are to be properly evaluated and recommended to the farmers only after it has given good performance. This involves planned field trials during the crop season. In thresher evaluation the amount of crop available at the farm of the Institutes is very limited. The period of testing at proper crop and operating conditions is also limited. Therefore besides the test procedures, laboratory test, crop parameters the availability of crop at proper moisture levels is important. The shortage of manpower should be always fulfilled by contractual skilled worker to complete the job in time.

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Appendix I

Botanical and Local Names of the Crops

Crops	Name in Hindi	Botanical Name
Cereals		
Rice	*Chawal, Dhan*	*Oryza sativa*
Wheat	*Gehoon*	*Triticum sativum*
Maize	*Makka*	*Zea mays*
Barley	*Jau*	*Hordeum vulgare*
Oats	*Jaie*	*Avena sativa*
Sorghum	*Jowar*	*Sorghum bicolor*
Pearl millet	*Bajra*	*Pennisetum typhodeum*
Finger millet	*Ragi*	*Eleusine indica*
Pulses		
Gram	*Chana*	*Cicer arietinum*
Green gram	*Moong*	*Vigna radiata*
Black gram	*Urad*	*Vigna mungo*
Red gram (pigeon pea)	*Arhar, tuar*	*Cajmus cajan*
Soybean	Soybean	*Glycine max*
Pea	*Matar*	*Pisum arvense*
Cowpea	*Lobia*	*Vigna sinensis*
Cluster bean	*Guar*	*Cyamopsis psoraloides*
Oilseeds		
Ground nut	*Moongphali*	*Arachis hypogaea*
Mustard	*Rai*	*Brassica juncea*
Rape seed	*Sarsoon*	*Brassica campestris*
Linseed	*Alsi*	*Linum usitatissium*
Sunflower	*Suraj mukhi*	*Helianthus annuus*
Castor	*Rehri*	*Ricinus cummnis*
Sesamum	*Til*	*Sesamun indicum*

Fibre crops		
Cotton	*Kapas*	*Gossypium* spp.
Jute	Jute	*Corchorus* spp.
Sun hemp	*Sann*	*Crotolaria juncea*
Deccan hemp	*Patsan*	*Hibiscus cannabinus*
Sisal	*Seesal*	*Agave* spp.
Manila Hemp	*Manila sann*	*Abaca*
Other crops		
Coconut	*Narial*	*Theobroma cacao*
Areca nut	*Supari*	*Areca catechu*
Mango	*Aam*	*Mangifera indica*

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Appendix II

History of development of threshers and shellers in India from 1930 up to 2008

1. From 1950 three threshing units designs used on self-propelled and tractor operated combine harvesters were cross-flow type and their use continued up to 1972. These combine harvesters were imported from European countries and USA by large state and Central Govt. farms in India.
2. From 1957-1966 three designs of threshing units developed in India for threshing of wheat crop and are being used in wheat and multicrop threshing.
3. Hammer Mill Type Wheat-thresher developed by Sardar Sunder Singh, Friends Own Foundry in Ludhiana in 1958.
4. Wire loop type threshing developed in Japan around 1945. They are used even now for rice threshing in India and many Asian countries.
5. Power operated maize sheller were manufactured and supplied in northern states of Punjab, Rajasthan and Uttar Pradesh during 1960.
6. Paddy threshers L.C.T and PSG were manufactured in southern states at Madras and PSG Industries, Coimbatore, on the basis of spike tooth threshing unit, straw walker and cleaning unit around 1959-60.
7. Manual Table top model for shelling maize cobs were produced and introduced in India for the small farmers, 1960.
8. Wheat thresher was developed at design and development centre at Allahabad Agricultural Institute, Allahabad during 1966-67.
9. Mr. Pangotra, agricultural engineer of Punjab state developed drummy thresher for operation with electric motor of 5 hp size during 1964-65 for the farmers who were not having tractor but using electric motor for operation of pump.
10. Paddy thresher of pedal operated was manufactured and marketed during1960 by ASPEE Mumbai.
11. Mr Dandekar, Director Agricultural Implements, GOI, New Delhi, developed Paddy thresher of wire loop tooth type operated by pedal using cycle chain drive. It was evaluated at Vellayani in Kerala state as reported during ISAE convention at Bangaluru in 1967.
12. Mr S.N. Pradhan, Scientist at CRRI Cuttack, reported that paddy threshing with pedal thresher was not economical for rice farmers in Orissa state during 1967-68. The cost of threshing with traditional method was low and it was not the problem of farmers. It was useful only in rice varieties, which were hard to thresh and introduced in India during 1967.
13. In 1964-68 work on centrifugal type threshing was done at PAU Ludhiana and findings were encouraging for practical applications in developed countries and in India.
14. Mr Harrington, Agricultural Engineer of USA deputed in India developed and evaluated multiple crop thresher under programme of Ford Foundation, New Delhi during 1969-1970.
15. Dr Verma, at PAU Ludhiana developed

multicrop thresher for threshing of wheat and paddy using cross flow design of threshing unit during 1971. It did not make bruised straw and therefore straw bruising device was developed as an attachment.

16. Conference on mechanization of rice crop was organized by FAO and CRRI, Cuttack, India in 1972. Jacobi, Head of Agricultural Engineering at CRRI, Cuttack, discussed the status and scope of mechanization of harvesting and threshing of rice crop in India, Asian and other developing countries. He reported that available threshers could meet the requirements of local farmers.
17. Allahabad Agricultural Institute, wheat thresher (Allahabad) and IARI, New Delhi, Pusa- 40, wheat, rice thresher were developed and evaluations reported during 1968-69.
18. In 1972 axial flow thresher of one tonne per hour capacity was developed at IRRI at Philippines.
19. Soybean crop was introduced in India at States Agricultural Universities of Uttar Pradesh, Madhya Pradesh and Rajasthan form 1971.
20. Proposals for establishment of National Level Institute in Agricultural Engineering and All India Co-ordinated projects in design and development of farm machinery and Post-harvest technology were submitted to Govt. of India for funding on national level and were approved.
21. Allahabad thresher was produced by local Manufacturers as 'Sherpur Thresher' in Ludhiana Punjab State and became acceptable at farmers' level for threshing of wheat crop. It was also used for threshing of other crops by the farmers such as bengal gram etc.1972.
22. All India Co-ordinated projects for design and development of farm machinery and harvest and post-harvest technology were approved to be set up in the country 1974-75, at State Agricultural Universities and ICAR Institutes.
23. Studies on harvesting of rice crop at optimum levels for maximizing yield levels and recovery of maximum of head rice during rice milling at Kharagpur and in South India were conducted.
24. National Institute of Agricultural Engineering was at Bhopal. It was named as Central Institute of Agricultural Engineering, during February, 1976.
25. Regional Network of Agricultural Mechanization Project of UNDP- ESCAP was approved and started with the participation of eight Asian countries from 1978. This was to popularize harvesting, threshing, sowing and weeding equipment among the farmers of these countries. It was also to share the equipment developed and used in these countries.
26. IRRI, Philippines was involved to train the manpower in engineering discipline for mechanization of rice crop and helped in providing the axial flow rice threshers to the national Institutes for local production and popularization during seventies.
27. Axial flow threshing principles were used to develop multicrop threshers of rice wheat type at CIAE Bhopal, PAU Ludhiana and other centres during 1983-85.
28. Axial flow threshing principle was used for threshing of soybean crop at CIAE, Bhopal during 1984 to reduce the grain damage within acceptable limits.
29. Multicrop thresher was developed at CIAE, Bhopal. It was evaluated on number of crops grown in Madhya Pradesh during 1985-88.
30. Groundnut decorticators and for castor were developed and popularized under Micro Mission Programme on Oilseed production of Govt. of India during 1988

onwards.

31. Threshers for the field experiments were developed for the scientists during 1987-88 at CIAE, Bhopal. This included single ear thresher and plot thresher for helping scientist in conducting field experiments under mechanization of field plot experiments at State Agricultural Universities and ICAR Institutes.
32. Sunflower threshers of various types were developed at CIAE, Bhopal, PAU, Ludhiana; APAU, Hyderabad; UAS, Bangaluru and MPKV, Rahuri, in Maharashtra state during 1992-93.
33. Threshers for groundnut oilseed crop were developed. It involved the threshing of freshly harvested groundnuts at CIAE, Bhopal and TNAU, Coimbatore during 1994-95.
34. Development work on High Capacity Multicrop Thresher was started at CIAE, PAU and other Institutes during 1993-94 to encourage custom hiring services.
35. Threshers for pulse crops were given priority. The stripping type pigeonpea thresher was developed at CIAE, Bhopal and Pantnagar. A high capacity stripping type thresher was developed at CIAE, Bhopal during 2000-2001.
36. Ergonomic studies were conducted on the equipment supplied to the farmers under various technologies popularization programmes of Govt. of India for the safety of farm operators.

❑

Appendix III

List of RNAM countries involved in Research and Development of threshers and shellers and other farm machines.

- Bangladesh Agricultural Research Council, Farmgate, Dhaka, Bangladesh.
- Department of Construction and Agricultural Machinery, Ministry of Machinery and Electronics industry 46, Sanlihe Road, Beijing 100823. Peoples Republic of China.
- Central Institute of Agricultural Engineering, Nabi Bagh, Berasia Road, Bhopal, Madhya Pradesh 462038. India.
- Agricultural Engineering Research, Training and Testing Centre Ministry of Agriculture and Natural Resources P.O. Box 4, Karaj 31585, Islamic Republic of Iran.
- Centre for Development of Appropriate Agricultural Engineering and Technology Situgadong, legok, Tangerang, Tromolpos 2, Serpong 15310 West Java, Indonesia
- Agricultural Tools Factory Ltd. P.O. Box No.2 Birganj, Nepal.
- Farm Machinery Institute National Agricultural Research Centre Park Road, Islamabad, Pakistan.
- College of Engineering and Agro-industrial Technology University of Philippines; Los Baños, College, Laguna 4031 Philippines.
- Farm Mechanization Research Centre Maha Illuppallama, Sri Lanka
- Agricultural Mechanization Institute Rural Development Administration; 249, Seodun-dong, Suweon, Republic of South Korea.
- Agricultural Engineering Division Department of Agriculture; Bangkhen, Bangkok 10900, Thailand.
- Agricultural Engineering Division International Rice Research Institute P.O. Box 933, 1099, Manila Philippines and donor organizations.

❑

Appendix IV

List of Institutes involved in Research and Development and popularization of threshing and other agricultural machinery in India

1. Allahbad Agricultural Institute, Deemed University, Naini, Allahbad, Uttar Pradesh 211007
2. College of Agricultural Engineering, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.
3. Dr B. R. Ambedkar College of Agricultural Engineering and Technology, Etawah, Uttar Pradesh
4. College of Agricultural Engineering, P.O. Krishi Viswavidyalaya, Mohanpur 741 252. Dist. Nadia (West Bengal)
5. College of Agricultural Engineering, Tamil Nadu Agricultural University. Kumlur 621 712 (Tamil Nadu)
6. College of Agricultural Engineering, Punjab Agricultural University, Ludhiana, Punjab.
7. ICAR research complex, For North East Hill region, Bara pani, Shillong, Meghalaya.
8. Kelappaji College of Agricultural Engineering and Technology, Kerela Agricultural University, Vellanikara, Kerela.
9. College of Technology and Agricultural engineering, Rajasthan Agricultural University, Pratap Nagar, Udaipur, Rajasthan.
10. College of Agricultural Engineering, Sikkim, Bhutan 795 001.
11. College of Agricultural Engineering, JNKVV, Adhartal, Jabalpur. Madhya Pradesh
12. Faculty of Agricultural Engineering, Raipur, 492 012. Chhatisgarh.
13. Division of Agricultural Engineering, I A R I, Pusa, New Delhi 110012.
14. Jute and Allied Fibre Research Institute, Barrackpore, Kolkata, West Bengal.
15. Jute Technological Research Laboratory. 12, Regent Park Kolkatta 700 040. (West Bengal)
16. Department of Farm Machinery, Gujarat Agricultural University, Junagadh, Gujarat.
17. Central Institute of Agricultural Engineering, Nabi Bagh, Berasia Road, Bhopal 462 038 (Madhya Pradesh)
18. Agricultural Research Institute, Andhra Pradesh Agricultural University, Rajendranagar, Hyderabad, Andhra Pradesh
19. College of Agricultural Engineering and Technology, GBPUAT, Pantnagar, Dist. Udhamsingh Nagar. Uttranchal Pradesh.

20. Dr Anna Sahab Shinde College of Agricultural engineering, Mahatma Phule University of Agriculture,Rahuri, Dist. Ahmednagar, Maharashtra.
21. College of Agricultural Engineering, Marathwada Krishi Vidyapeeth, Parbhani, 431402 (Maharashtra)
22. College of Agricultural Engineering, PRD Krishi Vidyapeeth, Akola 444 104 (Maharashtra).
23. College of Agricultural Engineering, C.C.S U.A., Hisar, Haryana 125 004.
24. Coordinating Unit ICAR, Krishi Anusandhan Bhawan, Pusa Campus, IARI, New Delhi.
25. Tractor training and testing station, Sirsa Road, Hisar 125 001 Haryana.
26. Central India Institute of Tractor Training and testing, Tractor nagar, Budni-466 445 Dist. Sehore, Madhya Pradesh.
27. College of Agricultural Engineering Kerela Agricultural University, Vellanikara, Dist.Trichure, Kerela.
28. National Institute of Post Harvest Technology formerly known as Rice processing Centre, Thiruvarur. Dist. Thanvavjur, Tamil Nadu.
29. International Crop research Institute for the Semi Arid Tropics (ICRISAT), Patnacheru, Hyderabad.
30. Oil Technological Research Institute, Anantpur, Andhra Pradesh.
31. Tata Energy Research Institute Bombay house 24, Homy Modi Street, Bombay 400 023.
32. Banaras Hindu University, Agricultural Engineering Section, College of Agriculture, Varanasi 221 005.
33. Indian Institute of Management Vastrapur, Ahmedabad, Gujarat.
34. Bureau of Indian Standards Director (Food and Agric) Manak Bhavan 9, Bahadur shah Zafar Marg, New Delhi 110002.
35. Agricultural Engineering Department, Indian Institute of Technology, Hijli, Kharagpur, West Bengal 721 016
36. Hart Court Butler technological Research Institute, Kanpur, Uttar Pradesh.
37. College of Agricultural Engineering, University of Agricultural Science, Raichure, Karnataka.
38. College of Agricultural Engineering; Rajendra Agricultural University, Pusa, Smastipur, Bihar 848 125.
39. Central Mechanical Engineering Institute Mahatma Gandhi Avenue, Durgapur 713209 (West Bengal).
40. Institute of People Science and Engineering, Faculty of Agricultural Engineering, M. G. Gramodaya Vishwavidyalya, Chitrakoot, Dist. Satna, Madhya Pradesh.
41. Directorate of Agriculture Engineering, Govt. of Madhya Pradesh, Vindhyachal Bhawan, Bhopal.
42. Agricultural Engineer (Research) Putlighar, Bhopal, Madhya Pradesh
43. Production Manager, Govt. Implement factory, Bhubaneshwar, Odisha.
44. Department of Farm Machinery, Shere Kashmir University of Agriculture and Technology, Jammu & Kashmir.
45. Central Institute for research on Cotton Technology (ICAR), Adenwala Road,

Matunga, Mumbai 400 019.

46. Department of Agricultural Engineering, Assam Agricultural University, Jorhat 785 013, Asom.
47. Central Plantation Crop Research Institute (ICAR). P.O. Kudly, Kasargod 670 124 (Kerela).
48. Department of Agricultural Engineering, Indian Institute of Sugarcane Research, P.O. Dilkusha, Lucknow 226 002 (Uttar Pradesh).
49. Department of Agricultural Engineering. Acharya Narendradev University of Agricultural and Technology, Kumar Ganj, Faizabad, Uttar Pradesh.
50. Department of Agricultural Engineering. Indian Grassland and fodder Research Institute, Phuj Dam, Jhansi, (Uttar Pradesh).
51. Department of Agricultural Engineering, Central Arid zone Research Institute, Jodhpur, Rajasthan 342 001.
52. Department of Agricultural Engineering, Directorate of Pulse research, Kanpur, Uttar Pradesh 208024.
53. National Research Centre for Groundnut, Maharishi Dayanand Farm, Junagarh 362 002.
54. Central Institute of Post harvest Engineering, PAU Campus, Ludhiana, Punjab.
55. Central Institute of Research on cotton Technology, Ginning Training Centre, Nagpur, Maharashtra.
56. National Research Centre on Women in Agriculture, Bhubaneshwar, Odisha.

❑

Appendix V

List of Abbreviations Used

AAI	Allahabad Agricultural Institute, Naini, Allahabad, Uttar Pradesh
AAIUD	Allahabad Agricultural Institute Deemed as University, Allahabad
AAU	Asom Agricultural University, Jorhat, Asom
AIT	Asian Institute of Technology, Bangkok, Thailand
ANGRAU	Acharya NG Ranga Agricultural University, Rajendranagar, Hyderabad
APAU	Andhra Pradesh Agricultural University
BAU	Birsa Agricultural University, Kanke, Ranchi, Jharkhand
ASAE	American Society of Agricultural Engineers.
CIAE	Central Institute of Agricultural Engineering, Nabi Bagh, Berasia Road, Bhopal
cm	Centimeter
GBPUAT	Govind Vallabh Pant University of Agriculture and Technology, Pantnagar, UttaraKhand.
g	Gram
HAU	Haryana Agricultural University, Hisar, Haryana, presently known as Choudhary Charan Singh Agricultural University
HPKV	CSK Himachal Pradesh Krishi Vishwavidayalaya, Palampur, Himachal Pradesh
ICAR	Indian Council of Agricultural Research, Krishi Bhavan, New Delhi
IGFRI	Indian Grassland and Fodder Research Institute, Pahuj Dam, Jhansi, Uttar Pradesh
IISR	Indian Institute of Sugarcane Research, Lucknow, Uttar Pradesh
IIT	Indian Institute of Technology, Kharagpur, West Bengal
IRRI	International Rice Research Institute, Manila, Philippines
JNKVV	Jawaharlal Nehru Krishi Vishwavidyalaya, Adhartal, Jabalpur, Madhya Pradesh
KAU	Kerala Agricultural University, Tavanur, Kerala
Kg	Kilogram

MPKV	Mahatma Phule Krishi Vishwavidyalaya, Rahuri, Dist. Ahmednagar, Maharashtra
MPUAT	Maharana Pratap University of Agriculture and technology, Udaipur, Rajasthan, Previously it was known as Udaipur University, Rajasthan Agricultural University etc.
NDUAT	Narendra Dev University of Agriculture and Technology, Faizabad, Uttar Pradesh
NEH	ICAR Research Complex for North East Hill Region, Umiam, Meghalaya
NIAE	National Institute of Agricultural Engg, Silsoe, U.K.
m	Metre, Unit of length
min	Minute
OUAT	Orissa University of Agricultural and technology, Bhubaneshwar, Odisha
PAU	Punjab Agricultural University Ludhiana, Punjab
PDKV	Dr Punjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra
quintal	100 kg
RNAM	Regional Network of Agricultural Mechanization (An organization of United Nations Development Programme)
RAU	Rajendra Agricultural University, PUSA, Samastipur, Bihar
sec	Second
tonne	Tonne (1,000 kg)
Tonnes/h	Tonnes per hour
TNAU	Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu
UAS	University of Agricultural Science, Bangaluru and Raichure, Karnataka
UNDP	United Nations Development Programme

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THEORY AND APPLICATION OF

CROP THRESHING TECHNOLOGIES

The development of agriculture would require appropriate machines to sustain the ecosystem and needs of the rural population. The Government of India, through the Indian Council of Agricultural Research, New Delhi, has been trying to develop, test and popularize farm machines on the basis of local needs and agro-ecological conditions.

The local manufacturing was encouraged to reduce the final cost of machines essential for the farmers, as this eliminated transport and handling costs. It helped the farmers to directly interact with the manufacturer or fabricator to meet their requirements. The authors have compiled the large number of designs of threshers and shellers of different types suitable for many crops. The information on low cost threshing technologies developed and popularized is made available in this book. The aim is to help farmers use the machines to reduce the drudgery.

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